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ECOVIEW Environmental Consultants

ENVIRONMENTAL MONITORING
# of the
GEYSERS KGRA
and
ADJOINING POTENTIAL LEASING AREAS
with special reference to
weather, air quality, and water quality

Contract # YA-512-CT6-71

for the
DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

Submitted
Febuary 19,1976

James A. Neilson
President

BUREAU OF LAND MANAGEMENT
Library
Denver Service Center

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INTRODUCTION

Resource monitoring has become a valuable tool to those responsible for environmental protection. Monitoring establishes a base line from which to measure the success of environmental policies and/or the compliance with environmental quality standards.

In The Geysers KGRA, resource monitoring has been on a sporadic, piecemeal basis. Development has resulted in some environmental changes. In response, numerous entities have initiated programs to characterize these changes and to determine the current status of the area's basic resources. It is the consensus of involved parties that to avoid costly duplication and overlap of effort, an integrated information exchange, indicating research done and additional data required, is needed.

The Bureau of Land Management (BLM) is currently in the process of preparing an environmental survey in the Cow Mountain and adjacent areas. Broadscale baseline data are needed to complete the environmental studies and implement the leasing program.

In November, 1975, BLM requested ECOVIEW Environmental consultants to investigate the status of environmental monitoring programs within The Geysers KGRA and adjoining potential leasing areas. Our work plan was to search, abstract, and catalog all known informational and inventory data on water resources, weather, and air quality within the study area. Once this had been accomplished, recommendations on monitoring improvement were to be presented. Therefore, this report presents an abstract summary of research and special studies conducted within the study area, a catalog of data-collecting stations, and conclusions and recommendations relative to environmental monitoring programs within The Geysers KGRA.

This first effort is preliminary in terms of tangible evaluations and definitions of long-term monitoring needs. We stress this qualification for several reasons:

- Considerable effort was expended in identifying existing informational sources. However, due to the wide array of data sources, indexing errors or omissions are likely to occur.

- The overall objectives of any monitoring program must be properly defined. A monitoring program itself is not an objective, rather it is a means by which to obtain an objective. There are a multiplicity of environmental concerns relative to the study area. Federal, state, local, and private entities collecting data within the region are responsible for various functions and operate under somewhat dissimilar objectives. To put existing information to best use, as well as coordinate future monitoring to produce information suited for a variety of purposes, monitoring programs need to be broadly defined, rather than aimed specifically at the geothermal problem. A formal definition of data needs should be deferred until the environmental management objectives of all agencies and groups involved can be consolidated.

-- A more thorough examination of available data and the possible interpretations of data now being obtained is in order. Duplication of future monitoring efforts might thus be avoided.

-- An examination of data management requirements would be most useful in the design of a monitoring system. To our knowledge, the specifics of any planned data management system have not been detailed at this time.

GENERAL SUMMARIZATION OF FINDINGS

As of this writing, time has not permitted a detailed examination of various data's usefulness to BLM's monitoring purposes, nor have estimates been made of the level of effort needed to gather and organize this data into a more useful form. Any serious deficiencies in the current and planned monitoring operations cannot be identified until the available data is collected, carefully scrutinized and evaluated. To accomplish this, BLM should inform the various data collecting agencies of the bureau's needs, and begin consolidation of each agencies information on the KGRA in-house.

A supervisory group responsible for correlation of all existing data and direction of all future monitoring activities could be established.

The environmental impact reporting (EIR) process should be used to update and expand the existing data base. Use permits and construction permits should be conditioned on the provision of standardized environmental data to improve the regional data inventory. There needs to be required within the EIR process a uniform code for standards of performance governing; (a) the type and quality of input data for each supply field as site specific background, (b) correlation of such data within the EIR to show the interrelationships between environmental concerns, (c) collection and analysis of such data so that it corresponds to the regional monitoring system. All site specific data should be gathered over a period of at least one year prior to the granting of any drilling permits.

ECOVIEW has previously outlined minimum requirements for monitoring environmental quality (see Appendix I) at The Geysers in conjunction with the EIR for Union's geothermal leases on Big Sulphur and Squaw Creeks in Sonoma County. The environmental parameters requiring monitoring are:

1. Air Quality
2. Water quality
3. Aesthetic quality, including audial, visual, and odoral components
4. Hazard and safety, particularly of the physical environments, both geological and pedological
5. Ecosystem disturbance, particularly biological elements
6. Economic or social disturbance
7. Climate

All of these parameters were assessed and included on the basis of past and present performance of the industry at The Geysers. Inspection of other fields both here and abroad by ECOVIEW consultants encompass approximately the same parameters, but often for different reasons and with different intensities.

It should be clearly understood that each KGRA is environmentally different and the considerations important for one are not necessarily desirable or necessary in another. Therefore, any attempt to generalize from one to another KGRA should be done only after careful study of local conditions.

The interrelationship of the seven parameters are discussed and the theoretical base for data collection, integration, and assessment are presented in the Union EIR (cf. Appendix II). It is noted that a comprehensive information system is very complex, costly and must be continuous in operation. However, it could be an extremely valuable regional planning tool.

ECOVIEW believes there is an important preliminary decision that must be made prior to any decisions regarding the type and intensity of a monitoring system, i.e., the extent to which the industry will be required to contain emissions within a closed production system. If the decision is to insist on complete containment except, say, for well cleanout or well defined emergency situations, then the necessity of air quality monitoring need only include several well placed base stations and a few mobile stations. If the decision is to permit situations similar to those currently at The Geysers (even with power plant scrubbers), then:

1. An intensive air quality monitoring system will be necessary, centered mostly in the KGRA but with additional stations downwind that extend to the Sacramento Valley.

2. Secondary stations recording periodic, synoptic air quality and air movement conditions need to be installed.

3. Several mobile recording units will be necessary to spot check conditions at trouble spots, etc.

4. The system will need to monitor for H_2S, SO_2, radioactive fallout, borate levels, acid rain, aerosols, and heavy metals.

Such a system will be costly and require trained personnel and special facilities: clearly the total containment alternative is the least expensive and by far the least hazardous.

In any case, sedimentation and increased runoff from impermeable surfaces will have to be monitored. Stations will have to be set up on minor tributaries in such a manner as to fix responsibility for geothermal discharge, as well as to protect the industry from sediments that are not its responsibility. Water quality data should have base stations on all key waterways. There should be also one or more well equipped mobile units capable of responding to emergency releases or accidents in order to immediately assess impacts and offer mitigation measures. Data should include full spectrum analysis at least once each year, preferably during the period of the first flush in the fall. Data collection for both sediment and water quality should be timed to runoff periods (early, peak and tail of each major storm) and not to fixed monthly or biweekly samplings, except perhaps on major perennial streams.

A prognosis of wind patterns over the KGRA by EVOVIEW's senior climatic consultant, Dr. John Carrol of U.C. Davis has been nearly completed. Several serious problems have been pointed out by this work:

(1) Apparent wind convergence over the northern and central Mayacmas range is indicated, this cannot be confirmed without an intensive study over that portion of the range. It is significant, because the air mass may move upward, northeasterly, or north (perhaps even easterly) under specific pressure patterns.

(2) The gap in wind stations is such that the pathway of air flow through the Clear Lake basin into the central valley cannot be verified.

(3) There is such a paucity of data northeast and southwest of Clear Lake that the relation of light winds and orographic features may mask wind distribution patterns.

(4) Lack of upper air wind movement data gives no indication of the mixing potential and relation to the depth and intensity of inversion patterns.

The report also suggests three separate weather station networks allowing different monitoring intensities, depending on the availability of equipment, financial support and personnel supplied to the project. This report will be added as an addenda to this study when it has been completed.

The framework into which the climate and air quality data should be placed is a predictive model of potential air transport and dispersion over the KGRA and perhaps (if the field enlarges to cover the KGRA as now identified) into the Sacramento Valley. Such a program is being considered by Lake County Air Pollution Control District in a proposal by Meteorology Research Inc. to the Environmental Protection Agency, #MRl P-710 305 4883. This proposal is a three phase program ultimately leading to a cell model covering a large rectangle from Cloverdale to Calistoga, but not including much of the BLM estate, and private lands to the north and east. Its concept is developed principally to serve Lake County, but includes portions of the other four counties because of the air pollution sources upwind from Lake County. Such a model is only as good as the input data and without: (1) vastly increased air movement data, (2) quantity and quality of pollutant release data from the existing field and (3) the cooperation of all agencies to furnish background data, the results of such an effort may be questionable.

At the risk of being redundant, we repeat the following to emphasize the importance of the prerequisite data base:

Climatic stations should be set up to provide continuous data on rainfall, humidity, temperature, incoming radiation, albedo, wind speed, direction, and frequency, for at least a 10-year period, then if necessary reduced to those parameters needed for adequate surveillance of developments as they occur. The distribution of stations should be such that they serve other uses, such as research stations, or vegetation and wildlife monitoring parameters. The air aloft should be monitored over the KGRA through the spectrum of weather patterns in the context of (1) air dispersion patterns, (2) inversions, (3) air quality modifications, and (4) moisture relationships with reference to premature condensation of moisture and subtle climate modifications.

It will also be essential to provide for the reduction of such data so that the fullest possible use can be made of it, not only for environmental uses but for research, planning and potential development of other resources. Likewise, all information should be gathered on a standard basis using approved methods of analysis and data reduction. Sampling must be done in a manner that is legally defensible. All data should be made public within 30 days of sampling dates. Hence all recording stations (private, county, state, and federal) need to be correlated under single supervision and responsibility. Full cooperation should be mandatory to assist local agencies and the industry in establishing an acceptable environmental base on which geothermal development can proceed with the confidence of all agencies and the general public.

WATER RESOURCES

Summary of Existing Studies and Monitoring Programs

Federal Agency Programs

U.S. Geological Survey.--Its objectives are to provide routine water resource information needs for all federal agencies through the operation of a network of water gaging and sampling stations, and by conducting specific studies on a contractual matching fund basis for cooperating agencies. The results are published in annual surface and ground water bulletins. In addition, office and open-file reports are published on the results of specific water resource investigations.

Environmental Protection Agency.--Its objectives are to determine compliance with federal water quality policy and standards; identify waste water discharges that require abatement or enforcement action at the federal level; conduct special investigations of water quality problems; and, coordinate activities of other federal and state agencies with monitoring responsibilities by utilizing a joint data system (STORET) for management of monitoring information. The EPA prepares office reports, publishes bulletins, and supplies data necessary for enforcement actions.

U.S. Bureau of Reclamation.--Its objective is to determine if water resources are adequately maintained in Bureau project waters and downstream waters for domestic, industrial and agricultural supply. Data are available in an annual published report titled, "Report on Operations," in published reports relative to specific facility operations, and in office reports.

U.S. Army Corps of Engineers.--Its objectives are to determine, in cooperation with other federal agencies, the physical, chemical, and biologic effects of dredging projects; provide input to investigations of flood control needs; and conduct prototype monitoring to verify physical model facilities. Data are available in office reports.

State Agency Programs

State Water Resources Control Board and Regional Water Quality Control Boards.--Objectives are to determine if water quality policy and objectives are being maintained for protection of beneficial water uses. Data are obtained through waste discharger's self-monitoring programs, staff checking activities, and data obtained from special surveys conducted by other agencies at the board's request. Data are available in the form of special reports, periodic reports, and evidence for enforcement cases.

Department of Water Resources.--Objectives are to measure and make known base-level quantity and quality of the state's ground, surface, and waste-water resources; and to note changes in base-level quality of these water resources as they may be affected naturally, or by man's activities. With the exception of stream sediment data, all data collected are reported in an annual publication series entitled, "Hydrologic Data, Bulletin No. 130- year." Stream sediment data are reported annually by the Department's cooperator, the U.S. Geological Survey, in the publication, "Water Resources Data for California, Part 2, Water Quality Records." Also, data are used in special studies and planning investigations and are reported in published bulletins of these programs.

Department of Fish and Game.--Its objective is to determine if water quality is being maintained for propagation and sustenance of aquatic life and wildlife in the waters of the state. Data are available in the form of office reports, reports and testimony to the State and Regional Water Quality Control Boards, and published documents.

Department of Public Health.--Objectives are to determine the safety, purity, and potability of domestic water supplies; detect the contamination of water from sewage or other wastes; and determine if public health standards are maintained in water contact recreation areas. Data are available in office reports, investigatory reports to the State and Regional Water Quality Control Boards, and published reports.

Other Programs

There are a number of private entities and local agencies (County Flood Control and Water Conservation Districts) involved in the collection of water resources data. The University of California has programs or studies that produce some types of water resources data. An important data source of waste-water characteristics and receiving water quality are the waste discharger self-monitoring programs required by the Regional Water Quality Control Boards. Monitoring is required of waste-water effluents (geothermal steam condensates) and of the environment in the vicinity of the discharge site.

Catalog of Data Collection Stations

The tables with this information are presented on the following pages.

Station	Latitude	Longitude	Period of Recording	Publication status	Temperature	Specific conductance	Turbidity	Color	Odor	pH (field)	pH (lab)	EH	Suspended solids	Other	Dissolved solids	Chlorides	Nutrients (N)	Nutrients (P)	Common ions	Hardness	Radiochemical	Dissolved oxygen	Other gases	Minor elements	Pesticides	Detergents	Biochemical oxygen demand	Carbon (total dissolved)	Coliforms	Other microorganisms	Other	Suspended sediment concentration	Suspended sediment particle size	Bed material sediment particle size	Other	Surface water station	Ground water station	Water stage or level	Water discharge	Travel time	Agency reporting
RUSSIAN RIVER DRAINACE																																									
EF Russian River at Potter Valley PH	39-21-42	123-07-38	1951 - 69	p	8	8	8	-	-	8	-	-	-	-	-	8	-	-	-	8	-	8	-	-	-	-	-	-	-	-	-	-	-	-	-	**	-	-	-	-	COO
EF Russian River nr. Calpello	39-14-48	123-07-45	1950 -	p	1	-	*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	*	*	*	-	-	-	-	-	-	GS
Russian R. nr. Ukiah	39-12-07	123-11-55	1964 - 68	p	*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	*	*	-	-	**	-	**	**	-	CS
Fk Mendocino IT Tower nr. Ukian	39-11-53	123-10-50	1964 - 68	p	1	-	*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	*	*	*	-	-	-	-	-	-	GS
EF Russian River nr. Ukian	39-11-45	123-11-30	1952 - 68	p&np	*	*	*	-	-	-	*	-	-	-	*	-	-	*	*	*	-	-	-	-	-	-	-	-	-	-	-	*	*	-	-	**	-	**	**	-	CS
Russian R. nr. Hopland	39-01-35	123-07-45	1951 - 69	p	8	8	8	-	-	8	-	-	-	-	-	8	-	-	-	8	-	8	-	-	-	-	-	-	-	-	-	-	-	-	-	**	-	-	-	-	COO
Russian R. nr. Hopland	39-01-35	123-07-45	1951 -	p	1	*	*	-	-	-	*	-	-	-	*	-	*	*	*	*	-	-	-	-	-	*	-	-	-	*	-	-	-	-	-	**	-	**	**	-	GS
Russian R. nr. Cloverdale	38-52-55	123-03-15	1963 -	p	1	*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	*	*	-	-	**	-	**	**	-	GS
Russian R. nr. Realdsburg	38-44-59	123-05-28	1951 - 69	p	8	8	8	-	-	8	-	-	-	-	-	8	-	-	-	8	-	8	-	-	-	-	-	-	-	-	-	-	-	-	-	**	-	**	-	-	COO
Dry Ck. nr. Cloverdale	38-44-59	123-05-28	1965 -	p	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**	-	**	**	-	GS
Dry Ck. nr. Ceyserville	38-41-55	122-57-25	1964 -	p	1	-	4	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	8	-	-	**	-	**	**	-	GS
Maacama Ck. nr. Kellogg	38-38-25	122-45-45	1963 - 67	p	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	*	*	-	-	**	-	**	-	-	GS
Russian R. nr. Healdsburg	38-36-48	122-50-07	1951 -	p	1	*	*	-	-	-	*	-	-	-	*	-	*	*	*	*	-	-	-	-	-	*	-	-	-	*	-	-	-	-	-	**	-	**	**	-	GS
Russian R. nr. Cuerneville	38-30-00	122-56-05	1951 -	-	1	*	*	-	-	-	*	-	-	-	*	-	*	*	*	*	-	-	-	-	-	*	-	-	-	*	-	8	8	-	-	**	-	**	**	-	CS
Russian R. at Cuerneville	38-30-00	122-56-05	1951 -	p	6	6	6	-	-	6	-	-	-	-	-	6	-	-	-	6	-	6	-	-	-	-	-	-	-	-	-	-	-	-	-	**	-	-	-	-	C06
Big Sulphur Ck. above Units 1 & 2	38-47-54	122-48-08	1968 -	np	5	5	5	5	-	5	-	-	5	-	-	-	5	-	5	-	-	5	-	5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	C06
Big Sulphur Ck. above Unit 3-4	38-48-10	122-48-52	1968 -	np	5	5	5	5	-	5	-	-	5	-	-	-	5	-	5	-	-	5	-	-	-	-	-	5	-	-	-	-	-	-	-	-	-	-	-	-	C06
Big Sulphur Ck. above Squaw Ck.	38-49-26	122-52-38	1968 -	np	5	5	5	5	-	5	-	-	5	-	-	-	5	-	5	-	-	5	-	-	-	-	-	5	-	-	-	-	-	-	-	-	-	-	-	-	C06
Squaw Ck. above Big Sulphur Ck.	38-49-28	122-52-38	1968 -	np	5	5	5	5	-	5	-	-	5	-	-	-	5	-	5	-	-	5	-	5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	C06
Big Sulphur Ck. nr. Cloverdale	38-49-21	122-59-07	1963 -	p	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	*	*	-	-	**	-	**	**	-	CS

Table 1. Water Quality Sampling Stations Within and Adjacent to The Geysers KGRA

Frequency of Measurement Code

1 - continuous
2 - seasonal
3 - daily
4 - weekly
5 - monthly
6 - quarterly
7 - annually
8 - other period
* - parameter measured but frequency not known or discontinued.
** - other types of water data activities at the site.

Agency Code

GS - U.S. Geological Survey
WB - U.S. Weather Bureau
C00 - California Department of Water Resources
C06 - California Water Quality Control Board

Publication Status

p - published
np - not published

Station	Latitude	Longitude	Period of Recording	Publication status	Temperature	Specific conductance	Turbidity	Color	Odor	pH (field)	pH (lab)	EH	Suspended solids	Other	Dissolved solids	Chlorides	Nutrients (N)	Nutrients (P)	Common ions	Hardness	Radiochemical	Dissolved oxygen	Other gases	Minor elements	Pesticides	Detergents	Biochemical oxygen demand	Carbon (total dissolved)	Coliforms	Other microorganisms	Other	Suspended sediment concentration	Suspended sediment particle size	Bed material sediment particle size	Other	Surface water station	Ground water station	Water stage or level	Water discharge	Travel time	Agency reporting
CACHE CREEK DRAINACE																																									
Clear Lake at Lakeport	39-02-36	122-54-48	1951 -	p	5	5	5	-	-	5	5	-	-	-	5	5	5	5	5	5	8	5	-	8	-	8	-	-	8	-	-	-	-	-	-	**	-	-	-	-	COO
Clear Lake at Lakeport	39-02-40	122-54-45	1951 - 66	p&np	*	*	*	-	-	-	*	-	-	-	*	-	*	*	*	*	-	-	-	-	-	*	-	-	-	-	-	-	-	-	-	**	-	**	**	-	CS
Highland Ck. above Highland Ck. Dam	38-55-45	122-55-10	1966 - 67	p	*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	*	*	-	-	**	-	-	**	-	CS
Highland Ck. below HC Dam nr. Kelseyville	38-56-54	122-54-03	1966 -	p	3	8	-	-	-	-	-	-	-	-	8	8	-	-	-	8	-	-	-	-	-	-	-	-	-	-	-	3	8	8	-	**	-	-	**	-	GS
Clear Lake nr. Clear Lake Highlands	38-58-05	122-39-40	1968 -	p	8	8	8	-	-	8	8	-	-	-	8	8	8	8	8	8	-	8	-	-	-	-	-	-	-	-	-	-	-	-	-	**	-	-	-	-	COO
Cache Ck. nr. Lower Lake	38-55-24	122-33-54	1951 -	p	5	5	5	-	-	5	5	-	-	-	5	5	5	5	5	5	8	5	-	8	-	8	-	-	8	-	-	-	-	-	-	**	-	**	**	-	COO
NF Cache Ck. nr. Lower Lake	39-01-06	122-33-54	1951 -	p	5	5	5	-	-	5	5	-	-	-	5	5	8	8	5	5	8	5	-	8	-	8	-	-	8	-	-	-	-	-	-	**	-	**	**	-	COO
Cache Ck. nr. Lower Lake	38-55-27	122-33-53	1953 - 66	p&np	*	*	*	-	-	-	*	-	-	-	*	-	*	*	*	*	-	-	-	-	-	*	-	-	-	-	-	-	-	-	-	**	-	**	**	-	GS
NF Cache Ck. nr. Lower Lake	39-01-10	122-34-00	1953 - 66	np	*	*	*	-	-	-	*	-	-	-	*	-	*	*	*	*	-	-	-	-	-	*	-	-	-	-	-	-	-	-	-	**	-	**	**	-	CS
Cache Ck. above Rumsey	38-54-47	122-16-14	1960 -	p	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	8	8	-	-	-	-	**	-	CS
Bear Ck. nr. Rumsey	39-56-35	122-20-40	1960 - 67	p	*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	*	*	-	-	**	-	**	**	-	CS
Bear Ck. nr. Rumsey	38-56-42	122-20-42	1968 -	p	5	5	5	-	-	5	5	-	-	-	5	5	5	5	5	5	-	5	-	-	-	-	-	-	-	-	-	-	-	-	-	**	-	**	**	-	COO
Bear Ck. nr. Rumsey			1968 -	p	5	5	5	-	-	5	5	-	-	-	5	5	5	5	5	5	-	5	-	-	-	-	-	-	-	-	-	-	-	-	-	**	-	-	-	-	COO
Cache Ck. nr. Capay	38-43-40	122-06-15	1951 - 66	p&np	*	*	*	-	-	-	*	-	-	-	*	-	*	*	*	*	-	-	-	-	-	*	-	-	-	-	-	*	*	-	-	**	-	**	**	-	GS
Cache Ck. nr. Capay	38-43-40	122-06-15	1951 -	on mag. stor. device	5	1	5	-	-	5	5	-	-	-	-	5	-	-	-	5	-	5	-	5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	COO
PUTAH CREEK DRAINACE																																									
Putah Ck. nr. Cuenoc	38-46-45	122-31-00	1960 -	p	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	8	8	-	-	**	-	**	**	-	CS
NAPA RIVER DRAINACE																																									
Napa R. nr. St. Helena	38-29-40	122-25-50	1951 - 69	p	8	8	8	-	-	8	-	-	-	-	-	8	-	-	-	8	-	8	-	-	-	-	-	-	-	-	-	-	-	-	-	**	-	-	-	-	COO
Napa R. nr. St. Helena	38-29-40	122-25-50	1953 -	p	1	*	**	-	-	-	*	-	-	-	*	-	*	*	*	*	-	-	-	-	-	*	-	-	-	*	-	*	*	-	-	**	-	**	**	-	CS
Napa R. nr. Napa	38-22-06	122-18-08	1969 -	p	8	8	8	-	-	8	8	-	-	-	-	8	8	8	-	8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**	-	-	-	-	COO
Redwood Ck. nr. Napa	38-19-05	122-20-35	1970 -	p	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	8	8	8	-	-	-	-	-	-	GS

Station	Latitude	Longitude	Period of Recording	Publication status	Temperature	Specific conductance	Turbidity	Color	Odor	pH (field)	pH (lab)	EH	Suspended solids	Other	Dissolved solids	Chlorides	Nutrients (N)	Nutrients (P)	Common ions	Hardness	Radiochemical	Dissolved oxygen	Other gases	Minor elements	Pesticides	Detergents	Biochemical oxygen demand	Carbon (total dissolved)	Coliforms	Other microorganisms	Other	Suspended sediment concentration	Suspended sediment particle size	Bed material sediment particle size	Other	Surface water station	Ground water station	Water stage or level	Water discharge	Travel time	Agency reporting
EEL RIVER DRAINAGE																																									
Lake Pillsbury nr. Potter Valley	39-24-30	122-57-30	1965 -	p	1	-	*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	*	*	-	-	**	-	**	**	-	GS
Eel River below Scott Dam nr. Potter Valley	39-24-30	122-58-15	1964 -	p	1	-	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	*	*	-	-	**	-	**	**	-	GS
Potter Valley PHT nr. Potter Valley	39-21-42	123-07-38	1951 -	p&np	1	*	*	-	-	-	*	-	-	-	*	-	*	*	*	*	-	-	-	-	-	*	-	-	-	-	-	*	8	-	-	**	-	**	**	-	GS
MF Eel River above Black Butte R.	39-49-45	123-04-11	1965 -	p	5	5	5	-	-	5	5	-	-	-	5	5	5	5	5	5	-	5	-	-	-	-	-	-	-	-	-	-	-	-	-	**	-	**	**	-	GOO
MF Eel River above Black Butte R. nr. Govelo	39-49-45	123-04-11	1966 -	p	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	8	8	-	-	-	-	-	-	CS
Black Butte R. nr. Covelo	39-49-15	123-04-50	1964 -	p	5	5	5	-	-	5	5	-	-	-	5	5	5	5	5	5	-	5	-	8	-	8	-	-	-	-	-	-	-	-	-	**	-	**	**	-	COO
Black Butte R. nr. Govelo	39-49-15	123-04-50	1964 -	-	1	-	-	-	-	-	*	-	-	-	*	-	*	*	*	*	-	-	-	-	-	-	*	-	-	-	-	3	8	8	-	**	-	**	**	-	CS
MF Eel River below Black Butte R. nr. Covelo	38-49-35	123-05-30	1961 -	p	1	*	*	-	-	-	*	-	-	-	*	-	*	*	*	*	-	-	-	-	-	*	-	-	-	-	-	*	*	-	*	**	-	**	**	-	CS
Williams Gk. nr. Covelo	39-49-30	123-08-25	1965 -	p	5	5	5	-	-	5	5	-	-	-	5	5	5	5	5	5	-	5	-	-	-	-	-	-	-	-	-	-	-	-	-	**	-	**	**	-	COO
Williams Gk. nr. Covelo	39-49-30	123-08-25	1964 - 69	p&np	*	*	*	-	-	-	*	-	-	-	*	-	*	*	*	*	-	-	-	-	-	*	-	-	-	-	-	*	*	-	-	**	-	**	**	-	GS
Mill Ck. nr. Covelo	39-44-45	123-10-15	1965 -	p	5	5	5	-	-	5	5	-	-	-	5	5	5	5	5	5	-	5	-	-	-	-	-	-	-	-	-	-	-	-	-	**	-	**	**	-	COO
Mill Ck. nr. Covelo	39-44-45	123-10-15	1964 -	p	8	*	*	-	-	-	*	-	-	-	*	-	*	*	*	*	-	-	-	-	-	*	-	-	-	-	*	8	8	-	-	**	-	**	**	-	GS
MF Eel R. at Dos Rios	39-42-42	123-20-50	1958 -	p	5	5	5	-	-	5	5	-	-	-	5	-	-	-	5	5	8	5	-	8	-	-	-	-	-	-	-	-	-	-	-	**	-	**	**	-	GOO
MF Eel R. nr. Dos Rios	39-42-23	123-19-27	1956 -	p	1	*	*	-	-	-	*	-	-	-	*	-	*	*	*	*	-	-	-	-	-	-	-	-	-	-	-	3	8	8	-	**	-	-	**	-	GS
Eel R. above Dos Rios	39-41-20	123-21-30	1961 -	p	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	GS
Elk Gk. nr. Hearst	39-38-57	123-07-123	1965 -	p	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	8	8	-	-	**	-	**	**	-	GS
Eel R. nr. Dos Rios	39-37-30	123-20-25	1958 -	p	3	*	*	-	-	-	*	-	-	-	*	-	*	*	*	*	-	-	-	-	-	*	-	-	-	-	-	3	8	-	-	**	-	**	**	-	GS
Outlet Gk. nr. Longvale	39-37-05	123-21-20	1958 -	p	5	5	5	-	-	5	5	-	-	-	5	5	8	8	5	5	8	5	-	8	-	8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	COO
Outlet Ck. nr. Longvale	39-37-05	123-21-20	1958 -	p	3	*	*	-	-	-	*	-	-	-	*	-	*	*	*	*	-	-	-	-	-	-	-	-	-	-	-	3	8	8	-	**	-	**	**	-	GS
Eel R. above Outlet Gk. nr. Dos Rios	39-37-30	123-20-25	1958 -	p	5	5	5	-	-	5	5	-	-	-	5	5	5	5	5	5	8	5	-	8	-	8	-	-	-	-	-	-	-	-	-	**	-	**	**	-	GOO

Table 2. Stream Gaging Stations within and adjacent to The Geysers KGRA.

Agency Code

00--U.S. Geological Survey
01--California Dept. of Water Resources
02--Corps of Engineers, U.S. Army
81--Sonoma County Flood Control District

Type of Record Code

1 - Daily discharge, continuous
3R - Maximum discharge, and base flow small streams program
3X - Maximum discharge, crest stage program
5R - Monthly or yearly flow, synthetically determined
6 - Daily stage, river station, continuous
6X - Daily stage, river station, fragmentary
7 - Daily stage, lake or reservoir
8 - Daily contents, lake or reservoir
9 - Periodic discharge measurements

Equipment Code

1 - Permanent structure - recording gage
2 - Semi-permanent structure - recording gage
4 - Non-recording equipment only - staff gage, reference marker, and crest stage gage
9 - Telemark radio gage
0 - No equipment

Addition of C indicates temperature recorder.

Publication Status Code

1 - Not published, available at county offices
2 - Published in USGS Water Supply Papers
3 - Published in State Bulletin
4 - Published in Agency Report
5 - Not published, available in other public depositories
6 - Same as No. 1, except early periods published by USGS
9 - Not published, available at USGS office

Station	Latitude	Longitude	Period of Recording	Agency	Type of Data	Equipment Available	Publication Status
CACHE CREEK DRAINAGE							
Cache Creek nr. Capay	38-43-40	122-06-15	5/42 -	00	1	2	2
Cache Creek @ Rumsey	38-53.4	122-14.2	57 -	01	6X	9	5
Cache Cr, above Rumsey	38-54.8	122-16.2	10/59 -	01	1	2	3
Bear Cr. near Rumsey	38-56.6	122-20.6	10/55 -	01	1	2	3
Bear Cr. trib. near Wilbur Springs	39-00.7	122-21.5	9/59-10/69	00	3X	4	2
Cache Creek at Wilson Valley Dam			10/ -9/60	01	5R	0	5
Cache Creek near Lower Lake	38-55.4	122-33.9	1/41 -	00	1	2	2
Copsey Cr. near Lower Lake	38-53-3	122-35.8	10/60-9/68	01	1	2	2
Cache Creek, N.F. nr Lower Lake	38-55-27	122-34-50	30 -	00	1		2
N.F. Cache Ck. @ Hon Spr. nr. Clear Lake Oaks	39-09-56	122-37-08	1971 -	00	1		2
Cache Cr. at Lower Lake	38-55.5	122-36.6	1/01 -11/15	00	6	4	2
Seigler Cr. at Lower Lake	38-54.6	122-36.8	10/65 -	00	1	2	2
Burns Valley Cr. nr. Clear Lake Highlands	38-58.5	122-36.7	12/62-6/69	00	1	2	2

Station	Latitude	Longitude	Period of Recording	Agency	Type of Data	Equipment Available	Publication Status
Cold Cr. at Soda Bay Rd. nr Finley	39-50.4	122-49.1	10/49-9/50	01	1	4	3
Cold Cr. at Konocti Rd. @ Kelseyville	38-58.5	122-49.6	10/48-9/50	01	1	4	3
Kelsey Creek at Soda Bay Road nr Finley	39-50.5	122-50.2	10/48-9/50	01	1	4	3
Kelsey Creek near Kelseyville	38-55.7	122-50.6	10/46 -	00	1	2	2
Hill Creek at Soda Bay Rd. nr Finley	39-00.9	122-57.7	10/49-9/50	01	1	4	3
Hill Creek at State Highway 29 near Kelseyville	38-59.6	122-51.6	10/49-9/50	01	1	4	3
Hill Creek at Bell Hill Rd. nr Kelseyville	38-58.3	122-51.5	10/49-9/50	01	1	4	3
Adobe Cr. at Soda Bay Rd. at Finley	39-00.9	122-52.5	10/48=9/50	01	1	4	3
Adobe Cr. Bell Hill Rd nr Highland Springs	38-57.4	122-53.4	10/45-9/50	01	1	4	3
Highland Cr. below Highland Cr. Dam nr Kelseyville	38-56.9	122-54.0	12/65 -	00		2	2
Highland Cr. above Adobe Cr. nr Highland Springs	38-56.9	122-54.0	10/49-9/50	01	1	4	3
Highland Cr. nr Kelseyville	38-56.1	122-54.6	10/54-9/62	00	1	2	2

Station	Latitude	Longitude	Period of Recording	Agency	Type of Data	Equipment Available	Publication Status
Addse Cr. at Highland CF nr. Highland Spngs	38-56.2	122-53.1	10/49-9/50	01	1	4	3
Adobe Cr. nr Kelseyville	38-55.7	122-52.7	10/54 -	00	1	2	2
Manning Cr. at State Hwy. 29 nr Finley	39-00.7	122-53.9	10/48-9/50	01	1	4	3
Manning Cr. nr Hopland HY nr Finley	38-59.9	122-54.8	10/49-9/50	01	1	4	3
Clear Lake at Lakeport	39-02.6	122-54.8	1874- 11/73 -	00	1	2	2
Lyons Cr. nr Lakeport	39-05.7	122-55.0	9/62 -	00	3X	4	2
Middle Cr. above bridge south of Upper Lake	39-09.3	122-54.8	10/49-9/50	01	1	2	3
Clover Cr. at bridge south of Upper Lake	39-09.7	122-54.6	49-50	01	6		
Middle Cr. nr Upper Lake	39-12.5	122-55.5	11/49-3/59 59 -	02	1	2	1
Clover Cr. at Upper Lake	39-09.9	122-54.4	12/48-9/68	01	1	3	3
Alley Cr. above Clover Cr. nr Upper Lake	39-10.9	122-53.6	10/48-9/50	01	1	4	3
Clover Cr. nr. Upper Lake	39-10.4	122-52.7	11/48-4/59	02	1	2	3
Middle Cr. nr. Upper Lake	39-11.0	122-54.6	12/59 -	01	3X	4	3
Scott Cr. at Upper Lake	39-09.5	122-55.2	11/59 -	01	6	2	3
Doyle Cr. nr. L end Bachelor Valley	39-09.9	122-57.7	48-49	01	6		

Station	Latitude	Longitude	Period of Recording	Agency	Type of Data	Equipment Available	Publication Status
Doyle Cr. at Lo W Va. Rd. nr. Witter Sp.	39-10.4	122-57.7	10/48-9/50	01	1	4	3
Doyle Cr. at Up W Va Rd nr. Witter Sp.	39-10.9	122-58.1	10/49-9/50	01	1	4	3
Scott Cr. at bridge S. of Bachelor Valley	39-09.9	122-58.0	10/49-9/50	01	1	4	3
Hendricks Cr. nr Scott Va. Rd, Lakeport	39-05.6	122-57.8	10/49-9/50	01	1	4	3
Scott Cr. at Hidden Lake bridge nr. Lakeport	39-05.7	122-57.5	10/48-9/50	01	1	4	3
Scott Cr. nr Lakeport	39-03.7	122-56.9	10/60 -	01	1	2	2
Scott Cr. at Upper Lake	39-09.0	122-55.7	59 -	01	1		
Clover Cr Bypass nr Upper Lake	29-10.5	122-54.0	11/59 -	01	1	2	3
Phipps Cr. nr Lower Lake	38-59.9	122-33.3	9/62 -	00	3X	4	2
Cache Cr. nr Lower Lake	39-01.2	122-34.0	7/30 -	00	1	2	2
PUTAH CREEK DRAINAGE							
Milliken Cr at Napa	38-19-21	122-16-24	1970 -	00	9	-	2
Nevada Cr nr Knoxville	38-42.7	122-17.5	8/69 -	00		2	2
Adams Cr. nr Knoxville	38-42.3	122-17.7	9/64 -	00	1	2	2
Hunting Cr nr Knoxville	38-46.3	122-24.4	6/69 -	00	1	2	2

Station	Latitude	Longitude	Period of Recording	Agency	Type of Data	Equipment Available	Publication Status
Putah Cr. nr Guenoe	38-46.7	122-31.0	12/o4	00	1	2C	2
Dry Cr. nr. Middletown	38-44.1	122-38.8	7/59 -	00	1	2	2
Putah Cr. trib. nr. Whispering Pines	38-47.2	122-41.5	10/58 -	00	3X	4	2
Pope Cr. nr Pope Valley	38-37.8	122-19.9	12/60 -	01	1	2	2
NAPA RIVER DRAINAGE							
Julncay Creek @ Napa	38-17-09	122-16-29	1970 -	00	1	-	2
Napa Cr. at Napa	28-18.1	122-17.0	40 - 41 1970 -		1	2	4
Sarco Creek nr Napa	28-19-56	122-15-06	1970	00	9	-	2
Redwood Cr. nr Napa	38-19.0	122-20.1	7/58 -	00	1	2	2
Milliken Creek at Napa	38-19-21	122-16-24	1970 -	00	9	-	2
Milliken Ck. trib. nr Napa	38-20-06	122-16-46	1970 -	00	9	-	2
Milliken Creek nr Napa	38-20-19	122-16-06	1970 -	00	1	-	2
Napa River nr Napa	38-22.1	122-18.2	11/29 -	00	1	2	2
Napa R. at Oak Knoll	38-22.1	122-18.2	40 -	02	1	2	4
Dry Cr. nr Yountville	38-21.9	122-20.4	11/40-9/41	00	6	4	2
Dry Cr. nr Napa	38-21.5	122-21.9	1/51 - 9/66	00	1	2	2
Rector Res. nr Yountville	38-26.4	122-20.6	5/48 -	01	7	2	3
Conn Cr. nr St. Helena	38-28.9	122-22.4	11/29 - 9/59	00	1	2	2

Station	Latitude	Longitude	Period of Recording	Agency	Type of Data	Equipment Available	Publication Status
Lake Hennessey trib. nr Rutherford	38-29.0	122-21.7	10/58 -6/69	00	3X	4	2
Napa River nr St. Helena	38-29.7	122-25.8	10/29 -	00	1	2C	2
Sulphur Cr nr St. Helena	38-29.3	122-28.8	10/57- 9/67	00	3R	4	2
RUSSIAN RIVER DRAINAGE							
Austin Creek nr Cazadero	38-30.1	123-04.1	5/59-9/66	00	1	2	2
Big Austin Creek at Cazadero	38-32.2	123-05.3	9/59 -	00	3R	4	2
Ward Creek trib. nr Cazadero	38-32.5	123-06.3	8/61 -	00	3X	4	2
Russian R. at bridge at Monte Rio	38-28.1	123000.6	11/57 -	81	9	4	1
Russian R. nr. Guerneville	38-30.0	122-59.6	12/39 -54	00		2	2
Russian R. at Korbel	38-30.2	122-57.7	48 - 54			2	9
Russian R. nr Guerneville	38-30.0	122-56.0	12/39 -	00	1	2	2
Mark West Cr. at Hwy bridge at Fulton	38-30.4	122-45.4	4/40 -	81	9	4	6
Mark West Cr. at Mark West Springs	38-33.0	122-43.2	10/57	00	3R	4	2
Santa Rosa Cr. nr Santa Rosa	38-26.1	122-43.0	7/59 -	00	1	2	2
Santa Rosa Cr. at Santa Rosa	38-26.1	122-43.0	7/39 -	00	1	4	2

Station	Latitude	Longitude	Period of Recording	Agency	Type of Data	Equipment Available	Publication Status
Santa Rosa Creek nr Santa Rosa	38-27.4	122-37.8	7/59 -	00	1	2	2
Laguna de Santa Rosa nr Graton	38-27.2	122-50.1	2/40 -	00	7	2	2
Piner Cr. at Coffee La bridge at Santa Rosa	38-27.8	122-44.4	57 -	81	9	4	1
Santa Rosa Cr at Hwy bridge at Santa Rosa	38-26.1	122-43.2	2/57 -	81	9	4	1
Spring Cr at Yalupa Av. bridge at Santa Rosa	38-26.5	122-40.8	2/57 -	81	9	4	1
Metazas Cr. below Benn Ave. br. at Santa Rosa	38-26.3	122-41.3	2/57 -	81	9	4	1
Brush Cr. @ Brush Cr. Rd at Santa Rosa	38-27.3	122-40.3	10/57 -	81	9	4	1
Santa Rosa Cr at Res. Dr. Br. Santa Rosa	38-27.5	122-40.3	2/57 -	81	9	4	1
Mill Creek near Healdsburg	38-35.7	122-54.9	10/57 -	00	3R	4	2
Dry Cr. Trib. nr. Hopland	38-53-10	123-09-15	58 -	00	1		2
Russian R. nr Ukiah	39-12.1	123-11.9	8/11 -	00	1	2	2
Russian R. nr Redwood Valley	39-19.2	123-13.3	63 -	00	1	2	2
Russian R. E.F. nr Ukiah	39-11.8	123-10.4	10/51-6/56	00	1	2	2
Russian R. E.F. nr Ukiah	39-11.7	123-11.5	8/11 -	00	1	2	2

Station	Latitude	Longitude	Period of Recording	Agency	Type of Data	Equipment Available	Publication Status
Lake Mendocino nr Ukiah	39-11.9	123-10.8	11/58 -	02	8	1	2
Russian R. E.F. nr Calpella	39-14.6	123-08.2	11/41 -	00	1	2	2
Russian R. E.F. trib. nr Potter Valley	39-15.5	123-06.9	10/58 -	00	3X	4	2
Soda Ck. trib. nr Boonville	39-01-32	123-17-25	61 -	00	1		2
N.F. Big River nr Willits	39-20-50	123-31-25	61-69	00			2
Dry Cr. on Mill St. br. at Healdsburg	38-36.3	122-50.2	57 -	81	9	4	1
Dry Cr. nr. Geyserville	38-41.9	122-57.4	3/59 -	00	1	2	2
Dutcher Cr. nr. Asti	38-43.3	122-58.6	10/58 -	00	3X	4	2
Dry Cr. nr Healdsburg	38-43.2	122-59.8	10/39-9/42	00	1	4	2
Warm Springs Cr. at Skaggs Springs	38-41.8	123-01.4	10/57 -	00	3R	4	2
Dry Cr. nr Cloverdale	38-44.9	123-05.5	11/41 -	00	1	2	2
Russian R. nr. Healdsburg	38-36.8	122-50.1	12/39	00	6	1	2
Franz Cr. nr Kellogg	38-36.5	122-41.6	10/57 -	00	3R	4	2
Maacama Cr. nr Kellogg	38-38.4	122-45.7	10/58 -	00	1	2	2
Russian R.-Healdsburg	38-36-45	122-52	55 -	Weather Bureau	1		4
Sausal Cr. nr Healdsburg	38-40.7	122-48.2	10/57 -	00	3R	4	2

Station	Latitude	Longitude	Period of Recording	Agency	Type of Data	Equipment Available	Publication Status
Russian R. at Geyserville	38-42.8	122-53.6	12/10-1/13	00	1	2	2
Big Sulphur Cr. nr Cloverdate	38-49.3	122-59.1	6/57 -	00	1	2	2
Dry Creek Trib. nr Hopland	38-53.2	123-09.2	10/58 -	00	1	2	2
Russian R. near Cloverdale	38-52.9	123-03.2	7/51 -	00	1	2	2
Cummisky Cr. nr Cloverdale	38-54.0	123-05.0	9/57 -	00		0	9
Feliz Cr. nr Hopland	38-58.4	123-08.5	8/58-66	00	1	2	2
Russian R. nr Hopland	39-01.6	123-07.7	10/39 -	00	1	2	2
Slide Cr. nr Ukiah	39-04.2	123-12.6	10/58 -	00	3X	4	2
Robinson Cr nr Ukiah	39-05.5	123-12.6	10/57 -	00	3R	4	2
Yoakim Br. Geyserville on Dry Creek	38-41-55	122-57-25	62 -	weather bureau	1		5
EEL RIVER DRAINAGE							
Outlet Ck. nr Longvale	39-27.1	123-21.3	9/56 -	00	1	2	2
Eel R. at Willis Rdg. D s			10/10=9/66	01		0	
Eel R. at Hearst	39-29.6	123-12.7	8/10-8/13	00	1	4	2
Eel R. at Pine Mtn. D s			10/10-9/66	01	5R	0	
Cold Cr. trib. nr Potter Valley	39-26.3	122-45.6	9/69 -	00	3X	4	2

Station	Latitude	Longitude	Period of Recording	Agency	Type of Data	Equipment Available	Publication Status
Hull Cr. nr Potter Valley	39-32.6	122-55.6	9/69 -	00	3X	4	2
Corbin Creek nr Elk Ck.	39-32-56	122-43-28	1970 -	00	9	-	2
Five Sprs. Ck. near Elk Ck.	39-32.3	122-47.4	9/69 -	00	3X	4	2
Potter Valley PH trib. nr Potter Valley	39-21.7	123-07.6	12/o9 -	21	1	2	2
Eel R. below Dos Rios	39-44-15	123-22-15	11-66	00	1	4	2
MF Eel R. below Elk BT. R. near Covelo	39-49-45	123-04-11	67 -	00	1	2	2
Williams Cr. nr Covelo	39-49-30	123-08-25	61 - 69	00	1	2	2
Mill Ck. tr. near Covelo	39-51-20	123-15-45	62 -	00	3X	4	2
Short C. nr Covelo	39-49-50	123-40-56	58=69	00	1	2	2
Mill C. nr Covelo	39-44-45	123-10-15	56 -	00	1	2	2
Eel R. above Dos Rios	39-41-3	123-21.5	12/50-9/65	00	1	4C	2
Mill Ck. below Alder Ck. nr Covelo	39-50.5	123-16.6	10/61-9/65	00	1	2	2
Eel R. at Van Arsdale Dm. nr Potter Valley	39-23-20	123-06-55	09 -	00	1	2C	2
Alder Ck. nr Potter Valley	39-23-20	123-02-37	62 -	00	3X	4	2
Eel R. below Scott Dm nr. Potter Valley	39-24-30	122-58-15	22 -	00	1	2	2
Tomki Cr. nr Willits	39-25-10	123-13-40	63 -	00	1	2	2
Eel R. nr Dos Rios	39-37-30	123-20-25	66 -	00	1	2	2

Station	Latitude	Longitude	Period of Recording	Agency	Type of Data	Equipment Available	Publication Status
Fulweiter C. Tr. nr Willits	39-23-56	123-18-07	62 -	00	3X	4	2
MF Eel R. nr Dos Rios	39-42-23	123-19-27	65 -	00	1	2	2
Goforth C. nr Dos Rios	39-42-45	123-20-29	62 -	00	3X	4	2
Hulls Ck. nr Covelo	39-54.8	123-14.9	10/61 - 9/64	00	1	2	2
Eel R. MF at Dos Rios Dms			10/10 - 9/60	01	5R	0	
Elk Ck. nr. Hearst	39-38.9	123-07.2	7/64 -	00	1	2	2
Eel R. MF nr Covelo	39-48.6	123-08.2	9/11-9/23	00	1	4	2
Hammerhorn C. nr Covelo	39-56.7	122-59.8	10/69 -	00	3X	4	2
Black Butte R. nr Covelo	38-49.2	123-04.8	10/58 -	00	1	2	2
Eel R. MF below Black Butte R. nr Covelo	38-49.5	123-05.5	8/51-9/67	00	1	2C	2

Table 3.
Data available from the U.S.G.S.

Station	Latitude	Longitude	Period of Record*	D.S.	Hardness	Major Cations	Silica	Aluminum	Iron	Manganese	Major Anions	Flouride	Carbon	Nitrogen	Phosphorus	DO	BOD	COD	pH	Pesticides	Radiochemical	Sediment: suspended	Sediment: bed
Adobe Ck. at Adobe Ck Rd nr Kelseyville	38-56-10	122-52-54	1968				*							*	*								
Adobe Ck. at Br. on Finley Rd nr Kelseyville	39-00-15	122-52-18	1968				*							*	*								
Scott Ck above SF Scotts Ck. nr Lakeport	39-02-42	122-58-57	1968				*							*	*								
SF Scotts Ck above Br on Biggs Rd. nr. Lakeport	39-02-27	122-58-54	1968				*							*	*								
Scotts Ck nr Lakeport	39-03-45	122-56-50	1968 - 69	*	*	*	*		*		*	*		*	*	*			*				
Lower Blue Lake at culvert nr Upper Lake	39-09-45	122-54-36	1968 - 69				*							*	*								
Middle Ck at Br on Hwy 20 nr Upper Lake	39-09-45	122-54-36	1968 - 69				*							*	*								
Clover Ck. nr Upper Lake	39-10-26	122-52-57	1968				*							*	*								
Clear Lake in Rodman Slough nr Nice	38-07-06	122-53-06	1968 - 69				*							*	*								

* 1968 - 1969 records generally consist of 1 - 4 samples

Station	Latitude	Longitude	Period of Record	D.S.	Hardness	Major Cations	Silica	Aluminum	Iron	Manganese	Major Anions	Flouride	Carbon	Nitrogen	Phosphorus	DO	BOD	COD	pH	Pesticides	Radiochemical	Sediment:suspended	Sediment: bed
Steigler Ck at Lower Lake	38-56-10	122-36-48	1968 - 69				*							*	*								
Kelsey Ck at Kelsey Ck Dr. nr Kelseyville	38-57-12	122-50-09	1968 - 69				*							*	*								
Cole Ck at Cole Ck Rd nr Kelseyville	38-56-24	122-48-39	1968 - 69				*							*	*								
McIntire Ck at Cole Ck Rd nr Kelseyville	38-56-28	122-48-30	1968 - 69				*							*	*								
Cole Ck at Soda Bay Rd nr Kelseyville	39-00-27	122-49-04	1968				*							*	*								
Clear Lake at Lakeport	39-02-21	122-54-44	1968 - 69	*	*	*	*		*		*	*		*					*				
Clear Lake 3 mi. offshore nr Lakeport	39-03-48	122-52-27	1968 - 69				*							*	*								
Clear Lake 1 mi. offshore nr Lakeport	39-03=48	122-53-24	1968 - 69				*							*	*								
Clear Lake 100 yds offshore nr Lakeport	39-03-48	122-54-30	1968 - 69				*							*	*								
Clear Lake at Nice	39-06-45	122-50-45	1968 - 69				*							*	*								
Clear Lake at Lucerne	39-05-06	122-48-27	1968 - 69				*							*	*								
Clear Lake nr Clear Lake Oaks	38-55-31	122-36-48	1951 - 68	*	*	*	*		*		*	*		*					*				

Station	Latitude	Longitude	Period of Record	D.S.	Hardness	Major Cations	Silica	Aluminum	Iron	Manganese	Major Anions	Flouride	Carbon	Nitrogen	Phosphorus	DO	BOD	COD	pH	Pesticides	Radiochemical	Sediment:suspended	Sediment: bed
Clear Lake in Horseshoe Bend nr Kelseyville	39-00-30	122-45-45	1968 - 69				*							*	*								
Clear Lake in Soda Bay nr Kelseyville	39-00=24	122-47-36	1968 - 69				*							*	*								
Clear Lake in Kelsey Slough nr Kelseyville	39-01-09	122-48-45	1968 - 69				*							*	*								
Clear Lake nr Quercus Pt. nr Lakeport	39-01-51	122-50-24	1968				*							*	*								
Clear Lake at Long Tule Pt. nr Lakeport	39-01-57	122-52-00	1968 - 69				*							*	*								
Clear Lake So. of Lakeport	39-02-03	122-54-21	1968 - 69				*							*	*								
Clear Lake nr 1st St. at Lakeport	39-02-33	122-54-21	1968 - 69				*							*	*								
Dry Ck. nr Middletown	38-44-07	122-38-52	1966	*	*	*	*		*		*	*		*					*				
Hunting Ck nr Knoxville	38-46-18	122-24-26	1971 -	*	*	*	*		*	*	*	*		*	*	*			*	*		*	
Adams Ck nr Knoxville	38-42-17	122-17-44	1970 -	*	*	*	*		*	*	*	*		*	*	*			*	*		*	*
Nevada Ck. nr Knoxville	38-42-42	122-17-31	1970 -	*	*	*	*		*	*	*	*		*	*	*			*	*		*	*

A Listing of Miscellaneous Water Resource Studies

California Department of Water Resources

1. Clear Lake Water Quality Investigation, 1966. Measurements taken throughout year 1964 at 31 stations.
2. Russian River Watershed Water Quality Investigation, 1968. Bulletin No. 143-4. Analysis of surface waters, 1965-66.
3. Upper Putah Creek Basin Investigation, Dry Creek Project, 1965. Bulletin #99-1. Dry Creek discharge data, 1905-1962.
4. Clear Lake--Cache Creek Basin Investigation, 1961. Bulletin No. 90.
5. Reconnaissance Report on Upper Putah Creek Basin Investigation, 1962. Bulletin No. 99.
6. Northeastern Counties Investigation, 1960. Bulletin No. 58.
7. Land and water use in Eel River Hydrographic Unit, 1965. Bulletin No. 94-8.
8. Land and water use in Russian River Hydrographic Unit. Bulletin No. 94-11.
9. Northeastern Counties Ground Water Investigation, 1963. Bulletin No. 98.
10. Alternative Eel River Projects and Conveyance Routes, Appendices A, B, C, D, & E. 1972.
11. Land and water use in the Putah-Cache Creek Hydrographic Unit, 1965. Bulletin No. 94-13.
12. Ten Counties Investigation, 1971. Bulletin No. 184.
13. Memorandum Report - Northern District, Revised Clear Lake Hydrology, 1969.
14. Surface water Hydrology of Putah-Cache Creek Hydrographic Unit, The Resources Agency office report, 1964.
15. Eel River Basin Environmental Studies, 1974 Progress Report.
16. Upper Eel River Development Report--Water Quality. Office Report, 1966.
17. Lake County Investigation, 1957. Bulletin No. 14.

18. The Department and its cooperator (U.S. Geologic Survey) monitor well levels and ground water quality in significant ground water basins throughout the study area. These data are published annually in DWR Bulletin 130-year.

U.S. Geological Survey

1. Ground water of the Lower Lake - Middletown Area, Lake County, 1955. Water Supply Paper 1297.
2. A Preliminary Investigation of Suspended Sand Discharge of the Russian River, 1971. Open-file Report.
3. Data for Wells and Streams in the Russian and Upper Eel River Valleys, Sonoma and Mendocino Counties, 1958. Open-file Report.
4. Geology and Ground Water in the Santa Rosa Valley Area. Water Supply Paper 1427.
5. Geology and Ground Water in the Russian River Valley Areas. Water Supply Paper 1548.
6. Data for Springs in the North Coast Ranges and Klamath Mountains of California, 1968. Open-file Report.
7. Sediment Transport in Cache Creek Drainage Basin, 1967. Professional Paper 562-A.
8. Sedimentation of Lake Pillsbury, Lake County, 1964. Water Supply Paper 1619-EE.
9. Turbidity and Suspended Sediment Transport in the Russian River Basin, 1971. Open-file Report.
10. Ammoniated Thermal Waters of Lake and Colusa Counties. Water Supply Paper 1535-A.
11. Geology and Ground Water in Napa and Sonoma Valleys. Water Supply Paper 1495.
12. Surface Water hydrology of California Coastal Basins between San Francisco Bay and the Eel River. Water Supply Paper 1851.
13. Relation of Turbidity to Suspended sediment in Northwestern California, 1966.
14. Nitrogen and Phosphorus Sources of Sediment Distribution in Clear Lake, 1968-69.

15. The Great South Coastal, San Francisco Bay Area Drainage . . . and North Coastal Basins, Chemical Analysis of Surface Waters, 10/59 - 9/60.

16. The Geological Survey has analyzed water quality at 2 sites east of Burmah Oil Company's lease CA-1862, Anderson Springs area, Lake County. The collection of data at The Geysers by the Geologic Survey is usually associated with environmental impact episodes, Environmental Analysis, and to insure lessee's compliance with regulations.

U.S. Bureau of Reclamation

1. "English Ridge Unit," Eel River Division, North Coast Project, 1972.

California Department of Fish and Game

1. Water Temperature Observations in the Eel River System, 1957-1967, A Data Report, 1972.

2. Turbidity Investigation of Big Sulphur and Squaw Creeks, October, 1975.

3. The Department has made periodic stream quality observations in The Geysers Area since 1965. The Department investigates reported geothermal waste discharges, recording such data as water temperature, pH, turbidity, electrical conductivity and water quality analysis for ammonia, sulfites, boron, arsenic and copper in discharge locales. These data are in the form of office reports.

4. Additional information (general stream surveys) covering a large percentage of the streams in the study area is also maintained on-file at the Region III office in Yountville.

Central Valley Regional Water Pollution Control Board #5

1. Pollution Study, Cache and Putah Creeks, Sacramento River Watershed, 1954.

California State Division of Water Resources

1. Flow and Quality Characteristics of the Russian River, Water Pollution Investigation Report #2, 1951.

2. Quality of Water: Russian River and Mendocino Coast Hydrographic Units, 1963. (San Francisco Bay District, Water Quality Unit)

U.S. Army Corps of Engineers

1. Flood Plain Information, Big Valley Streams, Kelseyville, California, 1974.

2. Design Memorandum No. 3, Lakeport Lake, Scotts Creek, California General Design, 1973.

3. Investigation of Mercury Hazard Potential, Warm Springs Dam and Dry Creek Basin. (Also U.S.G.S. open-file Report, 1971.)
4. Water Resources Development, Eel River, 1964.
5. Conservation Treatment of the Dry Creek Watershed, 1966.
6. Flood Control and Allied Purposes, Russian River, 1964.
7. Additional reports are available on Flood Control and Allied Purpose Investigations for Major Drainage Basins in the Study Area.

Department of Health, Education and Welfare, Public Health Service Region IX, San Francisco

1. Eel River Basin, Report on Water Uses and Future Water Quality Control Flow, 1962.

U.S. Forest Service

1. Dos Rios Reservoir--Impact Survey Report, 1969.

Federal Water Pollution Control Administration

1. English Ridge Project, Water Quality Control Study, 1969.

U.S. Department of Agriculture, River Basin Survey Staff

1. Conservation Treatment of the Dry Creek Watershed in the Russian River Basin, Sonoma and Mendocino Counties. Reconnaissance Survey Report.

Lake County Flood Control of Water Conservation District

1. Big Valley Ground Water Recharge Investigation, 1967.
2. Scotts Valley Recharge and Ground Water Distribution Investigation, 1970.

Napa County Flood Control and Water Conservation District

1. Napa County Water Resources Development Study

Sonoma Valley Soil Conservation District

1. An Inventory of Watershed Resources, 1965.

Other Studies

1. Burgg, R. H., 1972.
   Evaluation of Water Yield Potential in the East Putah Creek in the East Putah Creek Watershed under Multiple Use Management, University of California, Davis.

2. Wallis, J. R., 1965
   A Factor Analysis of Soil Erosion and Stream Sedimentation in Northern California, University of California, Berkeley. Unpublished Ph.D. dissertation.

3. Kaiser Engineers, 1968.
   "Task Force Report on Upper Eel River Routing Studies."

Special Studies

1. Parametrix, Inc. has conducted four studies over the past two years, as follows:

   a. A general study to determine the effects of geothermal development on the aquatic biota in Big Sulphur Creek and Squaw Creek. This study took place in the summer of 1974. Thirteen sampling stations were established, 8 on Big Sulphur Creek, 3 on Squaw Creek, and 1 each on Little Sulphur and Pieta Creeks. Six small tributaries of Big Sulphur Creek were also sampled. Continuous recording of Big Sulphur Creek temperature was made during the month of June. Water quality analyses include measurements of: stream flow, temperature turbidity, color, DO, pH, BOD, COP, alkalinity, H_2S, sulfate, nitrate N, nitrite N, ammonium N, oil, cyanide, settleable solids, filtrable, non-filtrable, and total residues, chromium, copper, silver, zinc, cadmium, mercury, boron, total organic carbon, lead, total N, arsenic, selenium, bormine, free and total chlorine and chlorinated hydrocarbons.

   b. Toxicity bioassays, challenging two species of fish with stream condensate from the various electricity-generating plants.

   c. A stream sediment/substrate study of Big Sulphur and Squaw Creeks to estimate the quality of trout spawning beds.

   d. A pre-development baseline study to evaluate the biotic communities in Alder, Lee, Kelsey and High Valley Creeks in Lake County.

Of these four studies, the final report for the first is completed. Reports on the other three studies are presently being prepared and will be available within the next few months. The studies were conducted under contract with Union Oil Company.

2. Battelle NW Laboratories is sampling water quality in the vicinity of Geysers Units 4, 8, and 11, and the Ottoboni State Wells 14, 16, and 20. The following parameters are being measured: heavy metals (mercury, arsenic, selenium, antimony, tellerium, and others), pH, Eh, ammonia, sulfide, and flouride (see discussion, air quality monitoring, special studies).

3. A cooperative study, involving Pacific Gas & Electric Co., the California Department of Fish and Game, and the U.S. Fish and Wildlife Service, has been established to inventory major streams in The Geysers area. Streambed sediment is being assessed in streams of the following drainages: Upper Kelsey Creek, Upper Putah Creek, and Big Sulphur Creek. Streambed samples are obtained upstream and downstream of all major tributaries. Stream discharge will also be measured.

   Fish populations are being assessed in streams of the Kelsey Creek, Upper Putah Creek, and Big Sulphur Creek drainages. Upper Adobe Creek, Pieta Creek and Sausal Creek will be surveyed as time allows. Water quality parameters will be routinely measured (conductivity, pH, DO, NH_4^+, turbidity, water temperature, and water velocity). Where natural or man-caused pollution is suspected or there is an unexplained absence of fishlife, a full spectrum analysis of water quality will be performed for that site. Reports will be completed by July, 1977.

4. Burmah Oil Corporation analyzed water quality in the Anderson Springs Geothermal Well Area from August 12 - 20, 1975. Chemical analyses were performed on samples taken from:

   -- Gunning Creek, upstream from Socrates Mine Road Bridge

   -- Castle Rock; Hot Springs drainage above subdivision

   -- Bear Canyon Creek, before confluence with Anderson Creek

   -- Anderson Creek, before confluence with Putah Creek

   -- Gunning Creek, upstream from Socrates Mine Road

   -- Castle Rock Creek, 500 ft. upstream from Anderson Creek

   -- Anderson Creek, at confluence with Putah Creek

   -- Bear Canyon Creek, 20 ft. upstream from Anderson Creek

Analysis included SO_4, Cl, HCO_3, CO_3, NO_3, Ca, Mg, Na, K, alkalinity, $CaCo_3$, total dissolved solids, suspended matter, turbidity, pH, specific conductance, F, B, Al, Mn, Fe, grease and oil and Hg.

5. Ammex Corporation is supporting the determination of the water quality in a number of streams in the mountainous area of northern Napa County. The information from this study is proprietary at this time.

Data Inadequacies

The information gathered to date suggests the following inadequacies in present routine water resource monitoring programs:

-- Stream gaging stations are placed on major streams but for minor tributaries and smaller drainage basins, at best, only short-term records exist.

-- Heavy metals that accumulate in body tissues, such as mercury, cadmium, copper, etc., have not been adequately monitored. There is limited available data on their source and occurrence within the environment.

-- Data on sources and occurrence of potential toxicants commonly associated with geothermal fluids, such as boron and ammonia, are limited.

-- Biostimulants, such as nitrogen and phosphorus, are routinely monitored where eutrophication of lakes and reservoirs is a concern. However, micronutrients, such as sulphur, potassium, iron, can also create biological problems. These trace elements have not been consistently monitored and base-level measurements are not available area-wide.

-- Normally, monitoring of geothermal chemicals and wastes is conducted by the discharger as directed by the Regional Water Quality Control Boards. Apparently, laboratory support for the Board's enforcement actions is limited. Private laboratory analyses utilized by waste dischargers may not be consistent with baseline data needs and may not be usable in a long-term monitoring program.

-- Major parameters of the aquatic ecosystem influencing biotic survival are the extremes over time in hydrogen ion activity, dissolved oxygen, and temperature. Generally, only the averages of these parameters are monitored. Dissolved oxygen depression for just a few minutes can destroy an entire population, even though the daily average value is optimum. The same can occur when hydrogen ion activity or temperature fluctuates beyond tolerable levels. Diurnal sampling, utilizing automatic recording sensors, is critical, especially in those areas where the toleration limits might be exceeded.

-- A consequence of watershed disturbance is soil erosion and sediment transport by excessive runoff. Sediment production is particularly critical in The Geysers KGRA region. Here slopes are steep and soils are derived from sandstone and shales. When disturbed, instability can develop, which manifests itself in soil slips of massive scale. The potential for adverse effects to aquatic communities, reservoir siltation, and loss of soil fertility is evident. However, little turbidity and siltation data have been collected; thus lack of background information is a problem in establishing water quality policies, and in evaluating the effects of development upon watershed ecology.

-- The total aquatic biota of a water body reflects both water and flow conditions. Biologic monitoring needs to be correlated with the observations concerning chemical and physical parameters.

-- The value of aesthetics is significant relative to the use and enjoyment of the aquatic environment. Nuisance conditions, such as odors, excessive biologic growth, foam, color, and other unsightly modifications of the water and surrounding environment, impair aesthetic enjoyment. Aesthetic impairment of stream courses and ponds are only reported randomly. Observations should be made periodically in those areas affected by waste disposal and development activities.

The above conditions need not be monitored continuously, but to use them as meaningful water resource indicators, natural background levels, fluctuations, and effects on beneficial water uses, should be known.

Conclusions

Present water resources monitoring activities have generally been designed to satisfy the immediate purposes of specific projects. The water quality and the stream discharge monitoring programs provide fairly adequate information to manage water for domestic, industrial, and agricultural purposes. Current programs, however, do not provide a completely adequate basis for an informed appraisal of environmental conditions within The Geysers KGRA. However, with time, more detailed site-specific information is being developed; but the information base for undeveloped areas and smaller drainage basins is lagging behind.

The data needs and activities of various government agencies concerned with water resource monitoring show many similarities. Cooperation in and coordination of monitoring activities has certain appeal. Integration allows increased sampling capability and more complete data utilization for a given cost. There is the potential for improved recognition of the relationship between environmental processes made possible by coordination of activities. Data analysis and sophisticated modeling capabilities may be more extensive when several agencies and groups are working together. Special expertise may be employed which otherwise might not be available to individual programs. Improved recognition of intermeshed relationships between agencies with various environmental responsibilities may result. However, operation of an efficient integrated program requires centralized control and budget management. Efforts to integrate such activities for mutual benefit already are taking place.

At the federal level, the U.S. Department of the Interior (office of Water Data Coordination) coordinates certain water data acquisition activities. This includes coordinating federal water data collection from streams, lakes, and ground water; operating a national network for acquiring and organizing data; maintaining a central catalog of information on water data and federal activities being planned or conducted to acquire water data. In California, the office of Water Data Coordination cooperates with the Department of Water Resources and the regional districts of federal agencies. The California Department of Water Resources and the Department of Fish and Game have extensive capabilities and support functions. The Department of Water Resources maintains a service capability for chemical, biochemical, and biological testing of water resources in addition to its climatological and stream gaging network. The Department of Fish and Game's capabilities include analysis of plankton, benthos, fish and aquatic plants, bioassays, and behavioral studies of aquatic life in response to water quality parameters. These departments regularly cooperate in investigations of mutual concern. In addition, the Department of Water Resources and the U.S. Geological Survey cooperate extensively in data collection and laboratory analyses.

Of the data management systems now in use to facilitate the exchange of basic data, no one system appears to contain all pertinent data available. Refinement in management of available data is possible, particularly data on biologic indicators of water quality.

Self-monitoring programs by waste dischargers, such as PG&E's, can be another important source of data. Unfortunately, the data from such studies are not always compatible with agency procedures. Self-monitoring programs have also been criticized on their feasibility. There is a need for increased coordination with governmental agencies and a standardization of sampling requirements and data presentation. Then some type of effective compliance check needs to be initiated before self-monitoring programs can realize their true potential.

Monitoring activities, themselves, have been stepped-up considerabley in the last two years. The present level of activity is commendable, but too late for good sound baseline data for areas already developed. It is important that this baseline data be obtained for those potential areas of development. Currently, only gross data are available, except perhaps in the Clear Lake vicinity.

It is not possible to recommend a specific monitoring program without a more detailed examination of existing programs and data, coordinating these into a usable base, and determining future data needs. However, future programs should be timed with more regard to the physical, chemical, and biological processes involved. Arbitrary observation schedules do not provide adequate information on cyclic variations in water flows and quality. Automatic, continuous recording is the preferred monitoring approach at locations subject to fluctuating waste loads, such as is evident in the developed geothermal field. In addition, surveillance of parameters having major biological significance, such as heavy metals, toxicants, biostimulants, should be increased.

Recommendations

A water resources monitoring program would encompass planned measurement and recording of the physical, chemical, and biologic conditions of the hydrologic process. The objectives of monitoring should be to determine if the water resource is being maintained and if water management objectives are being met. In conjunction with routine monitoring, special surveys could be carried out to supplement monitoring data; both types of programs must be considered when designing an overall monitoring program.

The value of a monitoring program is reflected in its ability to accomplish the following objectives:

(1) Establish an environmental baseline;

(2) Identify significant trends in environmental dynamics;

(3) Provide information to evaluate hydrologic and pollution control activities; and

(4) Develop an understanding of the hydrologic process and aquatic Ecology in the area being monitored.

In attaining these objectives, there are four major elements of concern:

(1) Hydrologic, physical, and chemical conditions: necessary information is obtained by monitoring water quantity and quality, and related parameters at selected points. This work is well underway within the study area, but needs to be expanded.

(2) Primary biologic effects: necessary information is obtained by observation of biologic conditions that are directly affected by use of the water resource, such as death of fish due to environmental stress. The Department of Fish and Game is actively involved in assessing this problem in The Geysers KGRA.

Until recently, observations were generally being made after a reported problem or accident occurred. Very little before-the-fact baseline data is available to properly assess the severity of problems brought about by geothermal development to date. For organisms with known tolerance levels, biologic effects may be monitored indirectly through observations of physical and chemical conditions.

(3) Higher biologic effects: indirect effects can occur in the aquatic ecosystem as a result of primary biologic effects. Biological magnification of mercury is one example. These may extend beyond the aquatic organisms to wildlife, agriculture, and man. Some private and academic studies are now under-way in this area. Much of this work should be classed as basic research which may or may not have immediate practical application.

(4) Use and control activities: water needs for beneficial uses must be established and knowledge of actions necessary to maintain flow and quality at desired levels must be gained. This is largely a planning and management function with monitoring providing feedback on the status of water resources. Water use needs are fairly well defined. However, the effectiveness of measures utilized to mitigate adverse effects of development in the region, such as hydromulching, slope contouring, and sediment trapping, needs to be carefully examined through the aid of monitoring.

For the interim, we recommend the following actions be taken in lieu of a fully-defined monitoring program:

(1) Expand the existing monitoring program operating within The Geysers KGRA. A major effort should be devoted to establish full spectrum base stations for all major subdrainage basins in the potential leasing areas outside the developed geothermal field. Hydrologic characteristics and ecological conditions of minor tributaries and drainage basins should also be monitored in sufficient detail for baseline referencing. These data are deemed essential where cause and effect analyses are to be made. The separability of present watershed activities and their incremental effect on downstream water conditions is a real problem. The combined gross effects of upland water uses (geothermal development, mining, grazing, quarrying, gravel extraction, farming, residential, and commercial development) are inextricably linked. Site-specific studies of the smaller drainage basins may resolve this problem and help fix responsibility for adverse impact.

(2) Before a long-term program commitment is made, it may prove advantageous to compile a preliminary environmental inventory of the developed Geysers area, utilizing the wide range of data available, and now being collated. Under careful analysis, this initial inventory may more precisely indicate the long-term information and basic data requirement necessary to satisfy BLM's objectives in a meaningful manner. A conservative approach at the beginning justifiable. In any event, significant lead times are needed to establish proper data bases. A year wisely spent initially could well be worth the delay.

(3) Adopt a working conceptual model depicting regional resources and their interrelationships to help define future data needs and guide data collection and analysis. One choice is the so-called Stanford Watershed Model, which has been generalized to fit most watershed configurations found in the western United States. This "predictive" model has been tested and verified for several large watersheds. The Stanford Watershed Model is quite sophisticated, but the results are only as good as the quality of the input data. Even a modest monitoring program to collect information for predictive purposes (for example, to confirm changes in stream flow regime or sediment production) would be an ambitious and costly task. Nonetheless, some conceptual model should be utilized.

An alternate approach might be the designation of a "test" watershed wherein data collection efforts are concentrated in a small, typical watershed, characteristic of The Geysers KGRA. Once modelled, this test watershed could serve as a surveillance area as well as provide needed outputs for future geothermal development. There are other systems-type models with various capabilities, some of which are available from the Hydrologic Engineering Center, a U.S. Government-supported research entity associated with U.C., Davis.

The model chosen should form the basis to determine if current programs are consistent with or satisfy the objectives of an adequate monitoring program.

(4) Ecological evaluations are needed. The hydrologic processes acting on a watershed involve several parameters: vegetation, climate, soil, topography, geology, as well as the type and intensity of surface activity. Particular consideration should be given to the consolidation of atmospheric monitoring data and other special studies (landslides, vegetation, land use, etc.) data within the final program.

(5) Monitoring of stream sediment could be improved if observation schedules were to coincide with runoff periods (early, peak, and tail) of each major storm.

(6) One or more equipped mobile units capable of responding to and speedily evaluating emergency waste discharges or accidents should be made available within the area.

(7) Long-range plans of all agencies involved in planning, surveillance, and development in the region should be determined so that all possibilities for interpretation or consolidation of monitoring efforts can be explored. In the event that a completely satisfying cooperative monitoring arrangement cannot be worked out, it would still be advisable that all recorded data be correlated under single supervision.

Parameters to Determine the Impact of Geothermal Development

The following list of parameters should be included in the overall program. The intensity or periodicity of measurement needs considerable investigation quided by:

(1) the extent of the geothermal resource

(2) the intensity of other resource uses within the same area

(3) the natural conditions of discharge and status of each water shed

Stream flow
Turbidity
Color
Temperature (air & water)
Dissolved oxygen
BOD, COD
Ptt.
Alkalinity
Solids: total dissolved,
settable & suspended
Electrical conductance
Coliform
Hydrogen Sulfide
Sulfates
total Nitrogen
Nitrite (N)
Nitrate (N)
ammonium
Phosphates

Carbonates
Oil and grease
Cyanide
Calcium
Potassium
Magnesium
Chlorine
Iron
Silica
Sodium
Mercury
Boron
Total organic carbon
Chromium
Arsenic, selenium
Cadmium
Zinc
Lead
Silver

Trace element monitoring should be based upon Battelle Laboratories findings and pre-development water quality analysis.

Appropriate biological water quality indicators need to be determined through research and consultation with water quality specialists such as Dr. Allan Knight, U. C. Davis. Similarly, aesthetic conditions should be recorded using a uniform system devised in consultation with appropriate environmentalists. Stream flow, temperature, electrical conductance, dissolved oxygen and ptt. should be monitored continuously at permanent base stations. All others should be monitored on a suitable basis for water quality determination.

CLIMATOLOGICAL OBSERVATIONS WITHIN THE GEYSERS KGRA

Summary of Findings

Approximately 200 routine climatological observation stations have been catologed for the study area. These stations vary widely in data collection capabilities, and type of data collected. The National Weather Service, the California Department of Water Resources, and various cooperators maintain the most extensive observation network in the region. Many other agencies just monitor wind velocities and direction. For the study area itself, this type of data is very limited.

Federal Agencies

The National Weather Service.--Besides its network of climatological stations. The N.W.S. conducts synoptic weather observations (3hourly) and airport Flight Service current weather (hourly) observations. These data are available on microfilm and microfiche as daily tabulations for each station. They can be obtained from the National Climatic Center, Asheville, North Carolina.

These data from its monitoring network are published mostly in daily, and for some cases, hourly summaries. These data are available from the U. S. Department of Commerce, National Oceanic and Atmospheric Administrator, Environmental Data Service. The publication is entitled "California Climatological Data."

State Agencies

The Department of Water Resources.--Its records are available directly from both the Sacramento and District Offices. They are also published periodically for the use of all interested agencies and the general public.

The California Air Resources Board.--It monitors wind in association with air quality monitoring. Wind data are taken on totalizing direction--speed instruments giving six hourly and daily summaries. However, information relevant to the study area has been collected for short-time periods only. For the past several years, year-round aircraft flights measuring temperature in the lower 923 m (300 ft) above ground surface are performed between 4:00 and 6:00 a.m. every morning at Ukiah, Red Bluff, and Sacramento. All ARB data should be available in Sacramento. Quarterly summaries are now being published, starting with the first quarter of 1974.

The California Division of Forestry, and Federal Division of Forestry.--These two agencies cooperate in recording wind speed and direction at 12:00 and 13:30 or 14:40 local time and/or an average for the 1.5 or 2.5 hour period during the fire season. Data taken since 1973 are stored with the U. S. Forest Service in Riverside, California. Several special studies have also been performed by CDF in which wind data were recorded every two hours during daylight hours, but only at certain stations and for limited periods. Most of these data are available through the Sacramento office of the CDF, but not in a highly organized form.

The California Division of Transportation (Cal Trans).--It operates wind recording stations (only for 1975) in the Bay Area. For many stations these data are not in a highly organized form. Again, occasional studies are performed locally for short periods. Microfilm data from the National Climatic Center for the period 1966-73 are on file with Cal Trans San Francisco.

Private Groups

Pacific Gas & Electric Co.--They have operated a continuous meteorological recording system at The Geysers Unit #11 since very late, 1972. At PG&E's request, additional sites have been equipped for micrometeorological observations by Environmental Systems, Inc., and Standard Research Institute in The Geyser's vicinity.

Catalog of Data

Tables presenting this data are on the following pages.

Table 4. Climatological Observation Stations.

○ - Non-recording
● - Recording
◐ - Both types

Operators Index Number

006 - Northwestern Pacific Railroad
403 - Sonoma County Flood Control & Water Conservation District
801 - Pomology Department, University of California, Davis
802 - Irrigation Department, University of California, Davis
806 - Department of Water Resources, Land and Water Use
808 - Division of Forestry
809 - Division of Highways - Maintenance Station
900 - U.S. Weather Bureau (Climatic Data, National Weather Service)
901 - Corps of Engineers, San Francisco District
903 - Corps of Engineers, Sacramento District
907 - State Climatologist

Note:

All stations measure rainfall, and all the precipitation data are available from the California Department of Water Resources. If the station is followed by (Eds), the data are also available from the U.S. Department of Commerce, National Oceanic & Atmospheric Administration, Environmental Data Service.

Station	Latitude	Longitude	Record Period	Cooperator's Index Number	Precipitation Only	Precipitation Temperature	Precipitation Temperature Evaporation
Adobe Creek	38-55-29	122-52-42	1946-	-	○		
Barney	38-55	122-52	1954-56	907			
Bartlett Springs	39-11-00	122-42-06	1933-48	900			
Cellier Place	38-47	122-42	1937-39	-			
Clearlake Highlands (Eds)	38-58	122-39	1954-	900		◑	
Clearlake Park	38-59	122-43	1923-54	900			
Clearlake Oaks 7E	38-59-54	122-33-22	1963-67			○	
Clearlake Oaks FFS	39-01-28	122-42-50	1959-63	808			
Clearlake Oaks	39-01-40	122-39-52	1960-	809			
Cobb	38-49-30	122-43-18	1923-			○	
Cobb 2NW	38-50	122-46	1961-	907	○		
Cordes	38-51	122-47	1954-61	900			
Cunningham	38-57-00	122-53-27	1954-		○		
Finley INNE	39-01	122-52	1954-		●		
Finley ISSE	38-58-58	122-52-30	1957-				
Finley 5SW	38-57-33	122-56-48	1957-			◑	
Guenoe Ranch	38-44-30	120-30-48	1931-40				
Harbin Hot Springs	38-47	122-39	1933-39				
H Bar H Ranch	38-50-54	122-36-18	1949-		○		
Helen Mine	38-44	122-42	1900-22	907			
Highland Springs Ranch	38-56	122-54	1954-61	900			
High Valley Mitchell	39-02-47	122-42-28	1958-			○	
High Valley Ranch	39-03-22	122-41-29	1961-				
Hobergs (Eds)	38-51	122-43	1930-	900	○		
Hopland 8NE	39-01	123-00	1939-	900	●		
Hullville	Sec. 14 T18N	R10W	1931-37				
Hullville 7SE	39-21	122-52	1907-09	907			
Hullville 4NW	39-27	123-00	1909-24	900			
Indian Valley	39-05	122-34	1948-54	900			
Kelseyville	38-58-33	122-49-53	1931-	900		○	
Kelseyville 2NW	39-00	122-51					
Kelseyville 2N	39-00-06	122-50-06	1935-	801		○	

Station	Latitude	Longitude	Record Period	Cooperator's Index Number	Precipitation Only	Precipitation Temperature	Precipitation Temperature Evaporation
Kelseyville 3SW	38-58	122-54		900			
Kelseyville 4SW	38-56-20	122-53-07	1916-60	900			
Kono Tayee	39-02-15	122-45-50	1874-1904	907			
Lake Pillsbury	39-25	122-58	1924-50	900			
Lake Pillsbury No. 2	39-25	122-59	1964-	900			
Lakeport 2NW	39-03-30	122-56-12	1929-				
Lakeport (Eds)	39-02	122-55	1901-	900			○
Lakeport 3W	39-02-48	122-57-48	1932-		○		
Lakeport USSC	39-02	122-55	1956-		●		
Lindblooms	38-44-42	120-37-54	1922-31				
Lower Lake 1W	38-54-42	122-38-00	1935-				
Lower Lake	38-54-48	122-36-29	1958-			○	
Lundquists	38-44-54	122-37-12	1922-				
Mahnke (Eds)	38-51	122-47	1954-	900	●		
Middletown (Eds)	38-44-53	122-37-05	1938-	900		○	
Middletown 7NW	38-47-54	122-42-18	1959-67			○	
Middletown 4WSW	38-44-14	122-40-30	1952		○		
Morgan Valley Stanley	38-53-10	122-28-30	1960-			◑	
Parramore Springs	39-18-54	122-52-42	1928-44	901			
Pitts Ranch	38-55-35	122-51-48	1956-				
Scotts Valley 3	39-03	122-56	1932	900			
Simons Ranch	38-47-24	122-44-00	1938 only				
Soda Bay	39-00-12	122-47-00	1946-64				
Soda Creek	39-25	122-59	1940-43	900			
Actna Springs	38-39-12	122-26-05	1924-38				
Angwin Puc (Eds)	38-34-17	122-26-05	1939-	900		●	
Atlas Rd. Dutra	38-26	122-15		900	●		
Altos Rd.	38-25-26	122-14-53	1940-	900	●		
Calistoga (Eds)	38-35-05	122-34-59	1873-	900		○	
Calistoga Williams	38-35-54	122-34-42	1929-				
Diamond Mtn.	38-33	122-35	1949-	403			
Hardin Ranch	38-34-42	122-20-42	1936-40				
Mt. St. Helena	38-40	122-38	1953-	900			
Mt. St. Helena	38-39	122-36	1901-12	907			
Oakville 1WNW (Eds)	38-26-46	122-25-07	1906-	900	○		

Station	Latitude	Longitude	Record Period	Cooperator's Index Number	Precipitation Only	Precipitation Temperature	Precipitation Temperature Evaporation
Oakville 4SW No. 2 (Eds)	38-23-55	122-27-54	1963-	900	●		
Veterans Home	38-23	122-22	1912-			○	
Yountville Gamble	38-26-05	122-22-05	1962-	806			
Cold Ck. Rch Guntley	39-243	123-119			○		
Bell Valley	39-01-30	123-17-36	1955-	901			
Boonville 6#SW	38-59-24	123-29-12	1945-				
Boonville HMS (Eds)	39-00-54	123-22-30	1936-	900			
Boonville Farrer	39-oo-48	123-22-12	1951-	901			
Boonville 3ENE	39-00-30	123-17-48	1955-				
Boonville Bell Valley	39-01-30	123-17-30	1960-				
Calpella	39-14	123-13	1922-42	901			
Cloverdale 8NW	38-49	123-10	1957-	403			
Coyote Dam	39-11	123-11	1960-	901			●
Foppiano Ranch	38-50-12	123-16-48	1958-	403			
Hopland 2 SE	38-57	123-06	1946-	403			
Hopland Field St. HQ	39-00-05	123-o5-o3	1952-	802			
Hopland Coon Lake St.	39-00-58	123-04-17	1952-	802			
Hopland Orchard St.	39-00-01	123-03-48	1952-	802			
Hopland Largo St.	39-01	123-07	1948-	900			
Hopland 8NE (Eds)	39-01-00	123-00-00			●		
Ornbaun Mailliard	38-55-00	123-18-06	1958-	403	○		
Potter Valley 3S	39-16-54	123-06-00	1953-	901			
Potter Valley 3NNW	39-22	123-08	1953-	900			
Potter Valley 3SE	39-18	123-04	1952-	900	●		
Potter Valley PH	39-22	123-08	1911-	900		○	
Redwood Valley	39-16	123-12	1937-	900	●		
Ridgewood Ranch	39-19	123-20	1905-48				
Talmage	39-08	123-11	1953		○		
Talmage SCS No. 13	39-08	123-09	1938-42	901	○		
Ukiah (Eds)	39-09	123-12	1877-	900		○	
Ukiah Sansoe	39-09-00	123-12-48	1945-				
Ukiah 4 WSW	39-08	123-17	1951-55	900	○		
Ukiah 4 SW	39-07	123-15	1939-51	900			
Ukiah 4W	39-09	123-16	1948-	900			
Ukiah FAA AP	39-08	123-12	1949-	900			

Station	Latitude	Longitude	Record Period	Cooperator's Index Number	Precipitation Only	Precipitation Temperature	Precipitation Temperature Evaporation
Ukiah Masonite	39-10	123-12	1952-58	900			
Willits 1 NE (Eds)	39-25	123-21	1950-	900		○	
Willits Howard RS (Eds)	39-21	123-19	1935-	900	●		
Sulphur Banks	39-00-00	122-39-48	1911-23	907			
Twin Valley	39-13	122-45	1914-23	907			
Upper Lake 2NE	39-11	122-53		900			
Upper Lake 7W (Eds)	39-11	123-02	1939-	900	○		
Upper Lake RS	38-10	122-55	1886-1967	900		○	
Willett SCS	38-55	122-58		900			
Stoneyford-Cooley	39-15-18	122-39-30	1935-	900	○		
Trough Spring	39-17-48	122-39-11	1964-	903	◐		
L sville Ranch	39-09-11	122-26-12	1950-	900	○		
Long Valley Garner	39-05-36	122-40-42				○	
Pope Valley 2E	38-36-57	122-23-21	1947-		○		
Pope Valley 3NW	38-38-22	122-27-18	1955-				
St. Helena (Eds)	38-30-25	122-27-40	1907-	900		○	
St. Helena 7NE (Eds)	38-33-56	122-22-53	1940-	900	●		
St. Helena 4WSW (Eds)	38-30	122-32			●		
Willits	39-22	123-20	1878-1941	907			
Willits NW Pac RR	39-24-12	123-21-06	1911-	006			
Yorkville (Eds)	38-54-18	121-18-46	1939-	900	●		
Calistoga 4NW	38-36-06	122-39-00	1931-	403	○		
Calistoga 3SW	38-32	122-38	1951-	403			
Calistoga 4SW	38-32	122-38	1950-	403	○		
Calistoga 5S	38-29	122-34		403	○		
Calistoga 9NW	38-38	122-42	1953-	403			
Cazadero	38-31-48	123-07-31	1939-	900	○		
Cazadero 9NW	38-36	123-13	1934-	403			
Cazadero 1N	38-32030	123-05-00	1953-	403			
Cazadero 7W	38-32	123-12	1941-	403			
Cazanoma Lodge	38-30	123-05		403			
Cloverdale	38-49	123-01	1877-1955	900			
Cloverdale 3SSE (Eds)	38-46	122-59	1950-	900		○	
Cloverdale 11W (Eds)	38-46	123-13	1939-	900	●		

Station	Latitude	Longitude	Record Period	Cooperator's Index Number	Precipitation Only	Precipitation Temperature	Precipitation Temperature Evaporation
Cloverdale Rch.	38-49-24	122-57-06	1958-	403			
Cloverdale Fire St.	38-47-18	123-01-00		403			
Devoe Rch	38-29	123-06	1948-	403			
Duncan Mills	38-27	123-04	1931-	403			
Elim Grove Cazadero	38-31	123-05	1955-	403			
Forestville 1N	38-29	122-54	1954-	403			
Forestville 2ESE	38-28-00	122-51-30	1955-	403			
Geyserville 2E	38-42-24	122-52-24	1934-	403			
Geyserville 2NE Albi	Sec. 17 TION R9W			403			
Geyserville 1NE	38-43	122-57	1951-58	403			
Geyserville HMS	38-42	122-54	1951-	809			
Geyserville 2N Barv	Sec. 6 TION R9W			403	○		
Guerneville	38-30-15	122-59-40	1939-	900			
Guerneville--city (Eds)	38-30	123-00	1924-40	901	○		
Guerneville Telemark	38-30	122-56		900			
Guerneville 4NW	38-33	123-01	1951-	900	○		
Healdsburg (Eds)	38-37	122-50	1977-	900			
Healdsburg FFS	38-39-12	122-52-18		403			
Healdsburg 2W	38-37-06	122-53-36	1940-	403		○	
Healdsburg 5E	38-37	122-45		403			
Healdsburg 7WSW	38-36	122-59	1953-	403	○		
Healdsburg 7NW	38-42	122-57	1958-	403			
Healdsburg 7SE	38-31	122-45	1951-	403			
Healdsburg 8N	38-43	122-51	1953-	403			
Healdsburg 8NW	38-42	122-58	1958-	403	○		
Healdsburg 2E	38-37	122-50	1943-	900			
Hedgepeth Ranch	38-39-24	123-12-36	1955-	403	○		
Hot Springs Rch.	38-47-18	123-07-00		403			
Kellogg (Eds)	38-40	122-40	1936-	900	●		
Knights Valley	38-37	122-40	1964-	900			
Lytton 4 NE	38-41	122-49	1938-	403			
Mt. St. Helen Trout Farm	38-42	122-39	1956-	403			
Oak Ridge	38-45	123-18	1953-	900			
Santa Rosa Sewage Plt.	38-26-24	122-45-12	1956			●	
Santa Rosa (Eds)	38-27	122-42	1888-	900		○	

Station	Latitude	Longitude	Record Period	Cooperator's Index Number	Precipitation Only	Precipitation Temperature	Precipitation Temperature Evaporation
Santa Rosa Beach	38-26-30	122-42-00		403			
Santa Rosa OFarrell	38-26	122-46		403			
Santa Rosa Pedranzini	Sec. 16 T6N R8W		1962-	806			
Santa Rosa Wilson	38-28	122-41	1953	403			
Santa Rosa 2S	38-24	122-42	1954-	403			
Santa Rosa 3N	38-29	122-44		403			
Santa Rosa 5N	38-31	122-43		403			
Santa Rosa 6NW	38-31	122-46		403			
Santa Rosa 7E	38-25	122-35	1949-	403			
Santa Rosa 7SE	38-24-00	122-36-30	1950-	403			
Santa Rosa 3W Fuller	Sec. 13 T7N R9W			403			
Santa Rosa 8N	38-33-06	122-39-00	1950-	403			
Santa Rosa 4NE				403			
Santa Rosa RS	38-27	122-46	1953	808			
Skaggs Springs Las Lomas (Eds)	38-40-38	123-08-04	1939-	900	○		
Skaggs Springs 2NE	38-43	123-00	1949-	403			
Skaggs Springs 2WNW	38-42-30	123-04-12	1945-	403			
Skaggs Springs 4W	38-43-00	123-05-30	1951-	403			
The Geysers (Eds)	38-48-02	122-49-32	1939-	403	●		
Venado (Eds)	38-37	123-01	1939-	900	●		
Windsor	38-33	122-56	1949-	403			
Wohler Pumping Plant	Sec. 29 T8T R9W		1960-	403	○		
Covelo	39-47	123-15	1921	900		○	
Covelo Eel River 2S	39-50	123-05	1940-	900	●		
Lake Mendocino Dam	39-14	123-11			●		
Covelo 1NNE	39-48-18	123-14-30	1952-57	801			
Dos Rios	39-43	123-21	1917-67	900			
Hearst Near	39-29	123-09	1910-16	907			

Table 5. Stations within the KGRA recording instantaneous wind speed and direction data.

Station	Type of Data	Period of Operation	Agency*
High Glade	2 obs. daily	fire season	FDF
Ukiah	- obs. every 3 hours - hourly obs. - continuous readings during pollutant sampling	daily daily 1/29-2/19/74	NWS FSS ARB - mobile unit
Leeville	- 2 obs. daily - obs. every 2 hours	fire season (before 1970) 6/71-10/71	CDF CDF (special)
Lakeport	- once at 8:00 a.m. - continuous readings during pollutant sampling	daily 1/8-1/28/74	Lake County APCD ARB - mobile unit
Clear Lake Highlands	- continuous readings during pollutant sampling	1/8-1/28/74	ARB - mobile unit
Clear Lake Oaks	- continuous readings during pollutant sampling	3/20-4/22/74	ARB - mobile unit
Konocti	- 2 obs. daily - obs. every 2 hrs.	fire season 6/71,72 - 10/71,72	CDF CDF (special)
Cloverdale	- 2 obs. daily - continuous reading during pollutant sampling	fire season 2/20 - 3/19/74	CDF ARB- mobile unit

Table 5. (Cont.)

Station	Type of Data	Period of Operation	Agency
The Geysers (Unit #11)	- cont. met. data - cont. met. data - cont. chart readings	-- after Dec. 1975 Sept. - Nov. 75	PG&E SRI (8 sites) FDDC (7 sites)
Middletown	- 2 obs. daily - continuous readings during pollutant ssmpling	fire season (before 1970) 2/26 - 3/18/74	CDF ARB - mobile unit
Healdsburg	- 2 obs. daily	fire season (before 1970)	CDF
Mt. Jackson	- 2 obs. daily	fire season	CDF
Sonoma Co. Airport	- microfilm	66-73	Cal Trans.
St. Helena	- 2 obs. daily - obs. every 2 hrs.	fire season 6/71-8/71	CDF CDF (special)
Santa Rosa Airport	- obs. every 3 hrs. - hourly obs.	daily daily	NWS FSS
Santa Rosa	- cont. MRI chart	74-75	Cal Trans

*

FDF: Federal Division of Forestry
NWS: National Weather Service
FSS: Flight Service Stations
CDF: California Division of Forestry
ARB: Air Resources Board
SRI: Stanford Research Institute
PG&E: Pacific Gas & Electric Co.
FDDC: Environmental Systems, Inc.

Miscellaneous Climatological Studies

1. Clear Lake Weather and Climate Study: Summary of Findings 1966-69, U.C. Agricultural Extension Service.
2. Climate of Sonoma County, 1964. Prepared by U.S. Department of Commerce, Weather Bureau.

Conclusions

In surveying available climatological data, it becomes evident that data are very inadequate for three principal areas which appear to be prime targets for geothermal development. These are: the higher elevations of the Mayacmas Mountains from The Geysers through the region north of Potter Valley; The Geysers south to Mount St. Helena (several short term records here); the higher elevation mountainous area east and southeast of Clear Lake.

Except for agricultural and populated areas, temperature data are limited throughout the region, and wind data are grossly lacking. The only stations recording wind movement are located in Santa Rosa and Ukiah. Several short-term (ARB) stations have been identified, but these were discontinued after as little as a month of operation. The remaining recording stations of note are Forest Service Stations in the area. Records prior to 1973 were not retained. Due to this lack of data, available wind records have little value for analyses of air movement and air pollutant transport.

Recommendations

To be able to determine the influences of future geothermal development on climatic factors and the influences of those climatic factors on geothermal emissions, current climatic conditions need to be known. The following recommendations are presented with a twofold purpose: one, to obtain the above objectives, and two, to integrate with planned and proposed air quality studies.

(1) Establish climatological observation stations to provide continuous data on rainfall, humidity, temperature, insolation, albedo, wind speed, and wind direction for those regions currently without adequate records. An observation period of at least 10 years should be planned. The distribution of these additional stations should be such that they serve other uses, such as research at experimental stations which may be established to monitor geothermal impacts.

(2) In developing fields, establish secondary stations recording air movement, to provide supplementary data for use in planned air pollution modeling studies. All such data collection should be coordinated through the county Air Pollution Control Districts.

The best data coverage would be a large array of numerous wind speed and direction sensors which give simultaneous read-outs of short-term (5-10 minutes) average wind speed and direction. Stations giving only long-term averages (i.e., wind passage), weekly, or monthly summaries of prevailing winds are not very useful.

(3) Monitor the air aloft to compliment existing and planned air pollution studies. It is particularly important to characterize regional air dispersion patterns and inversions.

(4) Monitor atmospheric moisture and temperature relationships. Information is needed to assess the impact of geothermal development on local humidity, heat-exchange capacities of moisture-laden air, icing characteristics,, fog and haze potentials. Monitoring of humidity can be conducted on a geothermal field basis. Monitoring of the other problem areas must be regional in scope.

AIR QUALITY MONITORING IN THE GEYSERS KGRA

Summary of Findings

State Agencies

California Air Resources Board.--The ARB operates mobile monitoring units of specified sites within the study area periodically throughout the year. These units are designed for continuous monitoring of air quality, usually measuring oxidants, CO, SO_2, S (total reduced), NO, NO_2, NO_x, total hydrocarbons, suspended particulate and lead. Wind data are taken at most of these locations on totalizing direction-speed instruments giving six hourly and daily summaries. All ARB data are available from the Sacramento office. Quarterly data summaries are now being published, starting with the first quarter of 1974.

Local Agencies

Lake County Air Pollution Control District.--The Lake County APCD has been monitoring ambient air H_2S since March, 1975. In addition to the H_2S measurement, wind direction, wind speed, and air temperature are recorded. Five sites have been monitored to date--all in the Cobb Mountain area:

- The Geysers Rock Area
- Adams Springs
- Two sites near Glenbrook at the northern end of Cobb Valley
- Anderson Springs

This program is being continued.

The District is in the process of expanding its operations and studies. It proposes to install sulfur analyzers south of Middletown, near the Napa County line, and another in Section 3, southwest of Hobergs. They hope to expand their knowledge of air movement patterns by releasing pilot balloons with radiosondes every six days for 2 1/2 years. The sondes will be sent up from Lakeport the first year, and from random spots around the county thereafter. Wind speed, wind direction, relative humidity, and temperature data will be recorded.

There are also plans to operate three particulate and three metal samplers every six days indefinitely. Information will be acquired on a size profile ranging from 0.1-15 μm in diameter. Sampling sites include Middletown, Anderson Springs, Whispering Pines, Hobergs, Adams Springs, Geysers Rock and Unit #13.

The District will soon begin operation of a laboratory for air quality analysis in Middletown. The station will be headquarters for monitoring H_2S, sulfates, aerosols, particulates, acid rain, and meteorological data.

Northern Sonoma County Air Pollution Control District.--Before an authority to construct a power plant facility or a permit to operate is granted, the APCD may require the applicant to provide and maintain such facilities as are necessary for sampling and testing purposes to provide information on the nature and extent of air contaminants discharged into the atmosphere. To separate man-caused emissions from natural emissions, the APCD conducted a study on the releases of emissions from natural sources in The Geysers area during the summer of 1975. This report has been published.

Private Studies

Battelle Pacific Northwest Laboratories.--Funded by the National Science Foundation, Battelle labs are conducting studies designed to characterize the quantities, physiochemical properties, and environmental accumulation of heavy metals released in geothermal emissions. They have 4 scheduled sampling periods of about 2 weeks duration at Units #4, 8, 11 and the Ottoboni State Wells 14, 16, and 20. Their last period is scheduled for May 1977. Parameters being measured in air are heavy metals such as mercury, arsenic, selenium, antimony, tellerium, and a number of others. H_2S is also measured. Lab analysis work is done by the Earth & Planetary Chemistry Section of Battelle, Northwest Laboratory, Richland, Washington.

A cooperative effort is being made by Pacific Gas & Electric Company to coordinate their environmental research interests in this area with Battelle's studies. PG&E has also supplied personnel to assist in the study.

Pacific Gas & Electric Company.--A routine survey has been conducted monthly since June, 1970, to sample ambient air at 36 locations within The Geysers area. These samples are taken only during daylight hours on fair weather days. The results of these surveys give area averages of H_2S concentrations over the past five years. This program is continuing as PG&E's H_2S abatement methods are being developed and as new geothermal development occurs.

A special monitoring program was conducted from August 25 to October 24, 1972, within The Geysers and immediate surrounding area, to determine the relative intensity of ground level H_2S concentrations. The collection network consisted of 48 stations. To supplement these data, a lightweight cup an vane wind system was installed near Units #7 and #8 on August 27, 1972. Study results have been published in the report, "H_2S Survey, Geysers Area," Robert N. Swanson and Margaret C. Mooney, PG&E, 1973.

Since August, 1973, H_2S and wind data have been measured at a location approximately 300 feet east of The Geysers Unit #11 plant site. The instrumentation (Houston Atlas Model 860 gas analyzer to May, 1974, and Houston Model 825R gas analyzer to date) has a fixed time base of three minutes. To compliment the study, ambient temperature, dew point temperature, and precipitation, are recorded from an installation approximately one mile south of the Unit #11 plant site, near Units #7&8. First year data are published in the report, "Hydrogen Sulfide Survey, Geysers Unit 11," Margaret L. Mooney, Meteorological Office, Gas Control Department, PG&E, 1974.

A mobile van equipped to measure H_2S and SO_2 in the atmosphere of The Geysers has been employed since July, 1974. The instrumentation essentially takes instantaneous samples.

PG&E, Union Oil, Burmah Oil, and Pacific Energy Corporation have contracted with Stanford Research Institute for a hydrogen sulfide monitoring network. This network includes eight automatic stations located in Sonoma and Lake Counties, including The Geysers, power plant Unit #13, the proposed Unit #15 site, Anderson Springs, Hobergs, Adams Springs, Sawmill Flat, and the Kahn Ranch (just north of Glenbrook). Each station records H_2S, wind direction and speed, temperature, dew point, and rainfall. In addition, an acoustic sounder will provide continuous mixing layer information. There is also a provision for limited acidity determination of rainfall. This network will be operated for 2 years.

Environmental Systems and Services, Inc. conducted a micrometeorological study previous to the selection of air monitoring sites. These data have not been statistically treated at this time and is not available for public distribution.

An additional air monitoring program is being considered. This program would measure ambient H_2S and SO_2 in the vicinity of Unit #4. This will be a relatively short, intensive study designed for early detection of any possible significant changes in air quality in the area.

PG&E and Union Oil have jointly funded a study of radon releases at The Geysers. This study has been underway since August, 1974; it is being conducted by Lawrence Livermore Laboratory and LFE Environmental Analysis Laboratory. Continuous radon monitors were installed at The Geysers in September 1975. LFE measured Ra^{226}, Rn^{222}, and Pb^{210} in environmental media and located several radon emission points. This portion of the investigation has been completed and the final report has been prepared. LLL is continuing field studies which are not scheduled to be completed until March 1976.

Union Oil Company.--Union Oil has been operating a particulate emissions monitoring station near the shopbuilding between Units #3, 4, 5 & 6.

Burmah Oil and Gas Company.--Burmah has been sampling ambient air for H_2S periodically since September, 1974. Sampling stations are located near the proposed Unit #13 plant site and at the center of the Unit field in Lake County.

Ammex Corporation.--Ammex has established two continuous H_2S monitors in the mountainous area of northern Napa County. At this time the study and its results are considered proprietary.

A Listing of Monitoring Stations

Air Resources Board Monitoring

Station	Date
Lakeport	1/9 - 1/29/74
Clear Lake Highlands	1/9 - 1/28/74
Clear Lake Oaks	3/9 - 4/22/74
Kelseyville	4/17 - 5/12/75
Upper Lake	4/23 - 5/8/75
Middletown	2/26 - 3/20/74
(2 stations)	4/16 - 5/12/75
Ukiah	1/29 - 2/19/74
(2 stations)	4/23 - 5/19/75
Willits	1/29 - 2/25/74
Cloverdale	2/20 - 3/19/74

Special Studies

Station	Date	Analysis
The Geysers	2/20 - 3/19/74	(H_2S only)
Anderson Springs	2/26 - 4/22/74	(H_2S and elemental analysis of particulates)

Conclusions

In general, there is a gross lack of baseline ambient air quality data for the region outside the developed geothermal area and its immediate area of influence. However, for proper analysis of air quality, the existing monitoring programs require a higher degree of coordination than is now evident. Standardization in instrumentation, data collection, analysis, and reporting is needed.

Available information is sufficient to begin the development of a KGRA emissions inventory defining locations, magnitude, frequency, pollutant concentrations, and relative contribution of geothermal emissions. However, the existing meterological data base is insufficient for a regional analysis of air pollutant transport and diffusion. Also, monitoring of sulfur dioxide has not been done at The Geysers. The significance of SO_2 pollution (H_2S reacts with ozone to form SO_2 and H_2) in this area is unknown.

Recommendations

Before a large-scale, long-term monitoring program is initiated, two steps should be taken: A centralized emissions inventory for the KGRA needs to be established. Prerequisites are a uniform geographic coordinate system for data logging, a uniform coding system for data reporting, and monitoring of emission sources as they develop. Also the current emissions abatement program needs to be evaluated to determine whether substantial improvement in emissions control is possible within a reasonable time period. Even with a 90% reduction in emissions, the air pollution potential of an expanded geothermal field may exceed the capacity of the air basin to dilute abated H_2S emissions to levels below the California ambient air quality standard.

If it is determined that a significant air quality problem will persist as a result of geothermal development, the following long-term recommendations are presented:

1. Define fundamental meteorological properties in the region, including:

    -- the local diffusion potential or ventilation index as a function of time of day, season, or synoptic situation. These in turn are functions of the local wind flow patterns and height to base of significant stable layers.

    -- the large-scale transport properties of the wind near the ground on both short-term and long-term scales, and in terms of transporting effluents from upwind sources to The Geysers area, and effluents from The Geysers to regions where other sources are active.

2. Based upon 1. above, expand the air quality monitoring network as necessary. Mobile recording units can be employed initially. The basic parameters that should be monitored are H_2S, SO_2, aerosols, particulates, and rainfall acidity. Radio-active fallout and heavy metal emissions can be periodically measured. Some of the monitoring should be the responsibility of the geothermal industry. Monitoring of SO_2 aerosols and rainfall pH should be approached on a much broader monitoring base and involved with fundamental research.

3. Require on-site monitoring in all pollutant discharge areas sufficient to define the nature and extent of emissions from specific sources.

4. Initiate or coordinate studies on possible reactions between emissions transported from The Geysers and pollutants active in other regions.

APPENDIX I

E. MONITORING PROGRAMS

The geothermal industry is still in the early development stage and many of its impacts are speculative or unknown. Many of these impacts are potential, others are real and immediate; some are direct, others are subtle; some are local, others are widespread. To insure a secure future for the industry without blights of short-sighted practices or subtle far-reaching effects that are initially ignored, environmental monitoring is essential. Current sampling and monitoring have often been variously sporadic, limited, and with few and sometimes poorly placed stations.

A review of impacts caused by geothermal development indicated areas where monitoring should be required to develop useful information. This information must eventually be placed into a regional context that would keep an intelligent perspective of balanced resource inventories, sustained yield, and long-term benefits. The initial framework of such a regional system is presented in Section XII.C: 272 . But the immediate requiremwnts for a monitoring program are categorized into the following:

(1) Air quality

(2) Water quality

(3) Aesthetic quality, including audial, visual, and odoral components

(4) Hazard and safety, particularly of the physical environment, both geological and pedological

(5) Ecosystem disturbance, particularly the biological elements

(6) Economic or social disturbance

Within each category or subgroup of it, the following elements should be obtained:

(1) origin of degradation

(2) threshold limits or minimum standards in relation to ambient, cumulative, or transfer conditions

(3) sampling strategy (i.e.,time and place)

(4) uniformity and reliability standards of analysis

(5) reduction of data and reporting forms

(6) data storage and retrieval

It is beyond the scope of this report to develop all the above categories for environmental subject areas, because there is insufficient data available to present a comprehensive integrated program. Areas not extensively discussed below will be discussed in subsequent EIRs as the need arises.

Our immediate concern lies with water, air, and noise monitoring. Some elements of hazard and safety that can be mitigated by immediate actions are found in Section VIII.B: 81.

1. Air Quality

Problems of air quality, including climatic changes, are on both a local and a regional scale. Some of the problems are the responsibility of local geothermal developers; others should be approached on a much broader monitoring base and involved with fundamental research.

Of immediate importance are:

Contaminants	Problem Area	Monitoring Objectives	Scope	Timing
Steam releases	humidity changes	extent, direction, and intensity	affected area	pre- & post-development
Aerosols	spectrum of contaminants	input & output, level & character	local & regional	pre- & post-development
Noncondensible	H_2S; spectrum of contaminants	dispersion pattern, concentration	local & regional	post-development
Steam & condensate contaminants	Boron, Hg & other toxic metals	dispersion pattern, concentration	local	post-development
Acid rain	Ph	level, incremental addition	regional	pre- & post-development

Humidity levels should be monitored in conjunction with both base stations and wind speed and direction stations in a network throughout the field. The network would establish seasonal and diurnal wind movements, incoming and outgoing humidity levels at the surface and aloft across the field.

Since so much is dependent on local and regional weather and the local patterns are so imperfectly known, no current monitoring program for other contaminants can present a completely accurate model of actual conditions.

It should be pointed out that the construction of an accurate model for temperature, moisture, and wind patterns can be extremely complicated and expensive to obtain. Until proven inadequate, a 15 to 20 station network, consisting of at least three continuous operating base stations monitoring the full spectrum of weather data (i.e., wind speed and direction, relative humidity, albedo, incoming radiation, precipitation, temperature), should be installed in the existing Geysers field. Subsidiary stations for daily or intermittent recordings of selected data should also be gathered on a synoptic basis to be correlated with base stations. Concurrently, climate aloft should be monitored in sufficient detail to relate an accurate pattern of dispersal for emissions. The tenure of base stations should be at least 10 years and subsidiary stations should be maintained or reactivated as fits their use.

Aerosols, noncondensible gases, and acid rain should be monitored in a coordinated program, since all three are closely related. This needs to be done on a regional basis with sufficient intensity on the direction of prevailing winds and air movement patterns, to determine the impact on adjacent dispersal areas and to deny or establish the contribution and importance of The Geysers-Clear Lake KGRA on the agricultural production areas of the Sacramento Valley. Aerosols, in particular, should be monitored on a continuous basis in such a way that incoming levels can be separated from outgoing levels. This will entail several stations in a transect across the field strategically placed to monitor surface dispersion patterns. Ground stations should be supplemented by regular surveys. When necessary measurements should be intensified to detect dispersal patterns under diverse weather patterns, including summer inversion and stagnant air masses.

The concept of air quality monitoring should be to establish the consequences of full field development under current field practices with those mitigations being currently applied. The tenure of base stations should be long enough to encompass several years of diverse weather patterns. At least one station in each major section of the KGRA should be permanent and operated continuously. The regular measurement of point emissions should continue within the field to detect well-to-well or area-to-area problems on a local basis. A periodic full spectrum analysis of emissions and condensate contaminants should take place in each portion of the field within each major section of the KGRA, to detect changes over a period of time.

While the latter is already done by several agencies, mostly independent of each other, the information remains scattered and subject to question because of variation in analysis standards and techniques.

Data need to be gathered in a comprehensive fashion, collected and reduced by a responsible agency, and made available within 30 days after collection to anyone wishing to use it. A comprehensive data retrieval system must be established on a long-term basis.

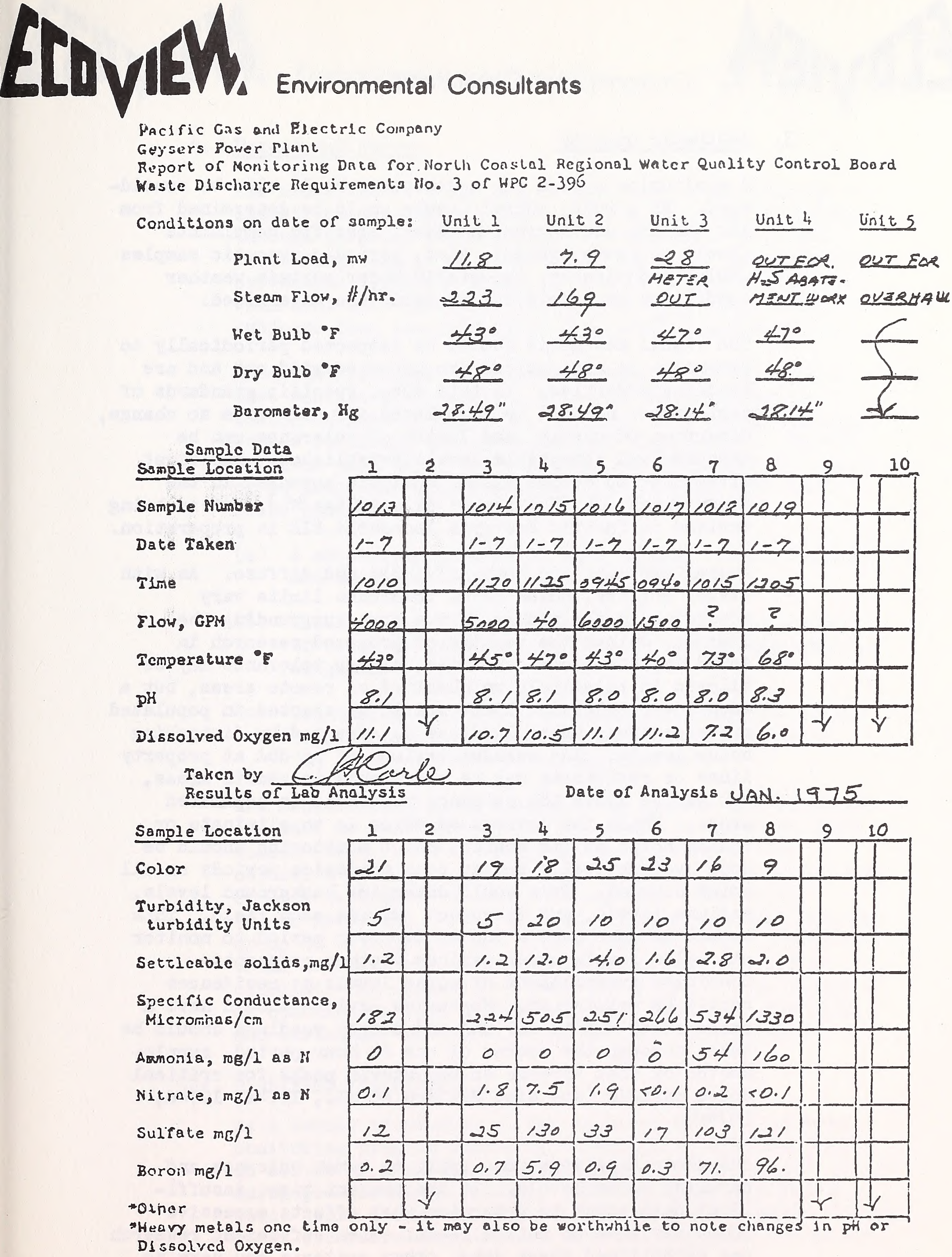
2. Water Quality

Comments on the existing methods and scope of water quality monitoring are made in Section XI.B.6:195. While the current program lacks important features, it is commendable that it has been done at all. The program needs to be improved to directly correlate with project area hydrology and sediment production; hence, a single monthly sample is quite inadequate.

A prerequisite to any project should be the development of a hydrologic model for each involved subdrainage. The hydrologic model would provide predictions, character of water flow changes, and prospective sediment loads (suspended and bottom) of pre- and post-development conditions. Predictions would be based upon the superimposition of a representative hydrologic period containing both "wet" and "dry" cycle years. The monitoring program needs to be oriented to the total flow regime of the various stream systems, rather than to a set time interval such as the monthly interval currently in use. Samples should be taken of interim flows, preferably just prior to predicted heavy precipitation, at least once on the rise, again near peak flow, and once in recession. Several gauging stations need to be installed where projects are contemplated if tributary flow is to be accurately measured. Installations are best made at least one year prior to the inception of field development and their tenure should be through the life of the field. To aid in the source identification of sediments or contaminants, whether geothermal, lumbering, mining, or other up-stream land use, main stream monitoring stations should be installed above project areas.

Figure VIII-3 is a sample of the monthly water quality reports made by Union Oil Company to the North Coastal Water Quality Control Board. Flow is estimated, and the elements sampled are only a few of the common or biosensitive materials known to be present in the field. Earlier, in Neilson et al., (1974a:158), detailed sampling procedures for water quality monitoring were discussed. So far, no reason has become apparent to depart from this program or basic strategy.

As with air quality, data need to be gathered in a comprehensive fashion by a single responsible firm or agency, collected, reduced, and interpreted within a few days after sampling. Data and results should become public property and available to anyone. The information should be placed in a central data bank equipped with an effective data retrieval system.



ECOVIEW Environmental Consultants

Pacific Gas and Electric Company
Geysers Power Plant
Report of Monitoring Data for North Coastal Regional Water Quality Control Board
Waste Discharge Requirements No. 3 of WPC 2-396

Conditions on date of sample:	Unit 1	Unit 2	Unit 3	Unit 4	Unit 5
Plant Load, mw	11.8	7.9	28	OUT FOR H2S ABATEMENT WORK	OUT FOR OVERHAUL
Steam Flow, #/hr.	223	169	METER OUT		
Wet Bulb °F	43°	43°	47°	47°	
Dry Bulb °F	48°	48°	48°	48°	
Barometer, Hg	28.49"	28.49"	28.14"	28.14"	↓

Sample Data

Sample Location	1	2	3	4	5	6	7	8	9	10
Sample Number	1013		1014	1015	1016	1017	1018	1019		
Date Taken	1-7		1-7	1-7	1-7	1-7	1-7	1-7		
Time	1010		1120	1125	0945	0940	1015	1205		
Flow, GPM	4000		5000	40	6000	1500	?	?		
Temperature °F	43°		45°	47°	43°	40°	73°	68°		
pH	8.1		8.1	8.1	8.0	8.0	8.0	8.3		
Dissolved Oxygen mg/l	11.1	↓	10.7	10.5	11.1	11.2	7.2	6.0	↓	↓

Taken by Carle

Results of Lab Analysis

Date of Analysis JAN. 1975

Sample Location	1	2	3	4	5	6	7	8	9	10
Color	21		19	18	25	23	16	9		
Turbidity, Jackson turbidity Units	5		5	20	10	10	10	10		
Settleable solids, mg/l	1.2		1.2	12.0	4.0	1.6	2.8	2.0		
Specific Conductance, Micromhos/cm	182		224	505	251	266	534	1330		
Ammonia, mg/l as N	0		0	0	0	0	54	160		
Nitrate, mg/l as N	0.1		1.8	7.5	1.9	<0.1	0.2	<0.1		
Sulfate mg/l	12		25	130	33	17	103	121		
Boron mg/l	0.2		0.7	5.9	0.9	0.3	71.	96.		
*Other		↓							↓	↓

*Heavy metals one time only - it may also be worthwhile to note changes in pH or Dissolved Oxygen.

Figure VIII-3 An example of the data sheet used by Union Oil in their monitoring program for the North Coastal Regional Quality Control Board.

3. Aesthetic Quality

A monitoring system for aesthetics should also be considered. As a rule, odoral levels could be determined from air quality monitoring; however, specific complaints should be investigated. Also, periodic synoptic samples would be advisable, especially under certain weather conditions once critical patterns are determined.

The visual aesthetic should be inspected periodically to determine if mitigations are being carried out and are becoming effective. In this area, specific standards of performance need to be formulated for each area so change, direction of change, and limits of tolerance can be measured and acceptable levels established. The first attempt at objective visual analysis appeared in the Squaw Creek EIR (Neilson et al., 1974g: 86), but is being revised in Pacific Energy's leasehold EIR in preparation.

Audial problems are both difficult and diffuse. As with visual quality, noise level tolerance limits vary according to the nature of the area surrounding the source. Unless the results of proposed research in sound impacts prove otherwise, higher tolerance may be allowed in relatively uninhabited or remote areas, but a much lower tolerance limit should be exacted in populated areas or areas where land use is affected by disturbing noise levels. The current maximum of 65 dbA at property lines or residences may be acceptable in remote areas, but may be above the nuisance threshold in populated areas. While the obvious solution is to eliminate or reduce noise at its source, point monitoring should be done systematically and at peak emisssion periods on all point sources. This would determine background levels, maximum levels, and frequency within each field. This should be done over a one or two year period to monitor all noise levels under various weather patterns. Continued surveillance of noise levels at residences should be maintained. Measuring devices should have a range of 45 dbA to 160 dbA and hourly readings should be taken through the course of one 24 hour period, supplemented by what appears to be interim peaks for critical noise periods (see also Neilson et al., 1974a, 1974d, 1974f).

The above considerations apply to human nuisance and damaging noise levels. At the present time, insufficient date exist to determine what effects excessive noise may have on native fauna. When sufficient research has established these data, other criteria may have to be developed.

4. Hazard and Safety

The more easily recognized hazards and safety aspects of industrial development are already under close scrutiny through in-house policy, agency policies, or required monitoring (e.g., the surveillance of radon gas, blowout prevention equipment during drilling). This discussion will deal with the not-so-obvious or less-interesting subjects from the production management standpoint.

As an introduction, our initial concern centers around mass wastage and landslide probability resulting in casing failure or blowouts, needless loss or expenditure of the resource, and environmental degradation. ECOVIEW believes that until the following are established, little or no drilling should be permitted in areas with landslide potential:

(a) A monitoring program of mass wastage rates, volumes, and depth for each section of the field.

(b) Installation of down-hole shutoff equipment capable of being triggered by departures from normal casing alignment.

(c) Initiation of a research program to identify potential landslide probability and to correlate with (a) above and hazard removal criteria.

The monitoring program should be on a scale and intensity at least of that done on the Eel River in Northern California (State Division Water Resource Study). The objective of the program would be: (1) to examine the rate of mass wastage in relation to expected field life; (2) to determine, if in the life span of a single well or group of wells, soil and subsoil movements are likely to break or shear casing by normal movements; and (3) to calculate the probability that the action either singly or in combination with unstable slopes, high soil moisture, and earthquake frequency, will trigger landslides.

5. Ecosystem Disturbance

As a result of studies at The Geysers, ECOVIEW believes a monitoring program should be attempted to estimate shifts in status or condition of biological elements in and around developed geothermal fields. Ideally, such monitoring would begin before or immediately on the development of the first successful exploratory well and continue throughout the life of the field. The program would include vegetation, wildlife, fisheries, and selected key elements in the food chain. The objective of vegetation monitoring would be to record disease, pest incidence relative growth, vigor, survival, etc.,of sample plots to be compared with control plots in undeveloped areas. Simultaneously, using appropriate sampling techniques, faunal numbers, population shifts, movement routes, reproduction, etc., should be monitored for both game and selected nongame species to determine the effects from an everexpanding steam field or series of fields. Such elements as habitat restriction, forage volumes, breeding-ground interference, etc., should be under the surveillance of a biologist. Clearly, the potential area of geothermal development is sufficiently large that the inception of local or large-scale changes should be recorded and analyzed to better maintain the compatibility of the geothermal resource with wildlife, forest, recreation, mining and watershed resources.

6. Economic and Social Disturbances

ECOVIEW has insufficient background data to develop a useful monitoring program for these elements, but they are clearly involved with resource management and interrelationships between the change from a rural to an industrial economy. Considerable impact, both positive and negative, may be realized from alternative or increased efficiency in the use of the heat exchange phenomena (cf. Section IX.D:223).

APPENDIX II

C. CONCEPTUAL FRAMEWORK FOR LONG RANGE CARRYING CAPACITY ANALYSIS AND INFORMATION MANAGEMENT

This section's objective is the conceptual development of a comprehensive framework and method for the recording, portrayal, and analysis of information required for the assessment of geothermal and other natural resource development proposals. Section IX.C:124 established the justification and over-all context of this system.

1. The Concept of Carrying Capacity

Carrying capacity is the ability of the landscape to sustain the use or extraction of a resource without jeopardizing the long-term productivity of that or other resources. In the case of nonrenewable resources, the desirable objective is extraction without depletion or disturbance of other renewable and nonrenewable resources. In the case of renewable resources, the desirable objective is sustained yield accomplished in a compatible manner with the sustained yield of other resources.

Based on these general criteria and objectives, information must be systematized and categorized into logical, manageable units. (For a technical introduction to the model, see Appendix V .) For some factors, carrying capacity can be defined in relatively inflexible terms. Determination of absolute limits, however, is an extremely difficult process. In the method selected, factors are disaggregated in the model, permitting separate and explicit determination of limits for many categories. Past experience and judgment has demonstrated that summing factors to arrive at a comprehensive notion of carrying capacity for any given model function is not a valid method for determining discrete and subtle limits. Summing generally cancels out or obscures the role of the less dramatic, but critical, factors. Therefore, a system of disaggregated accounts, portrayed separately, results in a better information pool on which political decisions can be based. Policy actions related to resource development may have a direct bearing on: (a) the stability of a particular factor in relation to its carrying capacity; and (b) the rate of integration and level of accumulation within any given factor or set of factors.

The following diagrams graphically illustrate the method and concepts developed to portray the Carrying Capacity Model. The overall scheme is shown in Figure XII- 9. There are four essential steps in the process: (1) inventory and periodic field assessment, (2) impact chain

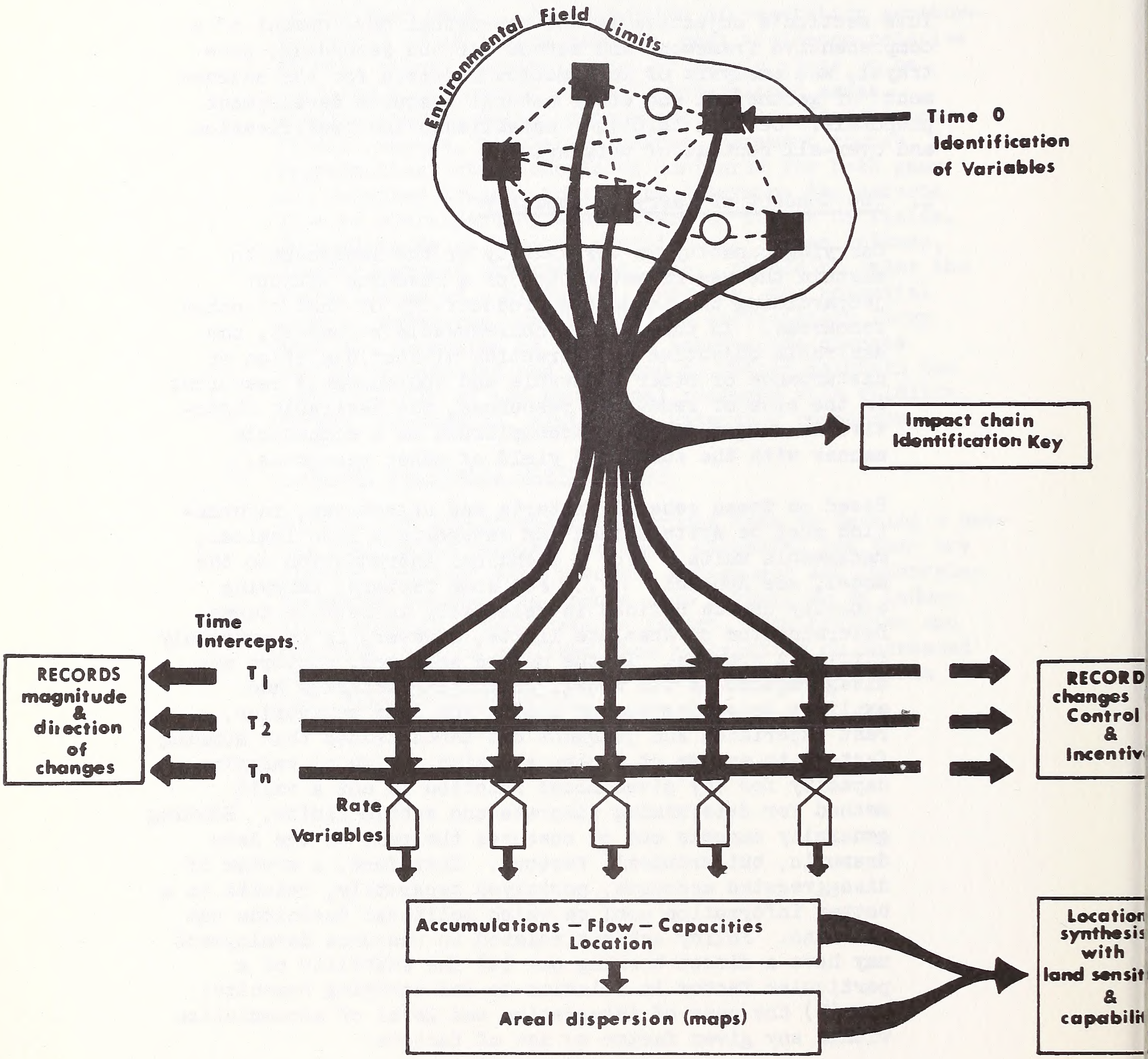


Figure XII-9. The four major steps recommended for developing the c carrying capacity model. (1) Inventory, (2) Impact Chains, (3) Monitoring and Analysis, (4) Mapping.

identification, (3) periodic assessment of changes, and (4) establishment of sensitivity and capability. The basic requirements for the first step in the process are: (1) the development of a critical item inventory matrix, (2) data storage and retrievable system, and establishment of a data compatibility system, (3) formulation of a coordinated monitoring program.

Impact chain identification is discussed in Section V.H: 61.

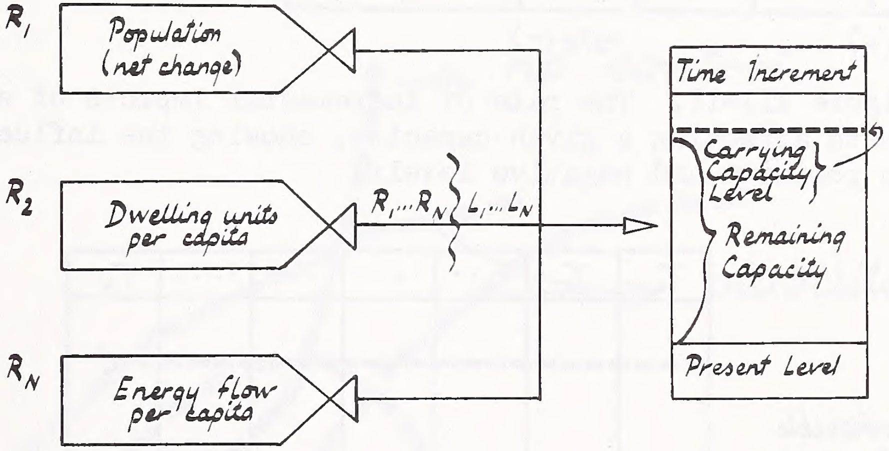


Figure XII-10. Rates (R) of selected impacts indicating changes translated into levels (L) in relation to resource capacity.

From the accumulation of activity rates and flows, the relation of cause and effect for explicite actions can be synthesized into an estimate of total impact. Figure XII-10illustrates the rate-level relationship translated into some actual or judgmental capacity.

Figure XII-11 shows the capacity concept over discrete time units reflecting positive and negative growth in relation to a stable capacity. Not all capacities are expected to remain stable because of technological modifications, changes in demand or direction. Figure XII-12 illustrates three types of capacity potentials. The sphere of influence may be local, regional or inter-regional in scope and within each the capacity potential must be observed and assessed periodically in conjunction with the examination of volume and flow changes.

With the information of capacity based on rates or levels, policy actions can be affected to (1) increase capacity, (2) stabilize or contain actions approaching capacity levels, (3) affect no control, etc. Figure XII-13 shows

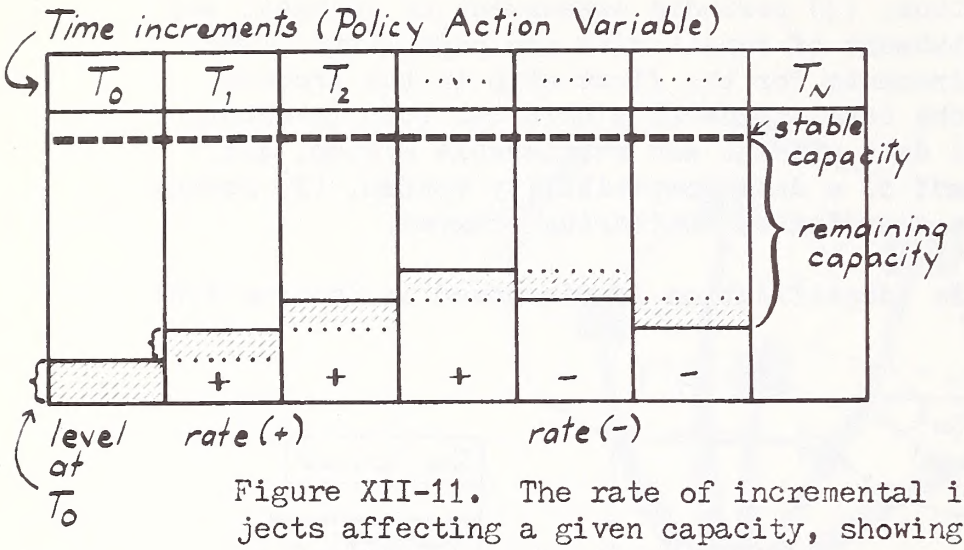


Figure XII-11. The rate of incremental impacts of suceeding projects affecting a given capacity, showing the influence over time on positive and negative levels.

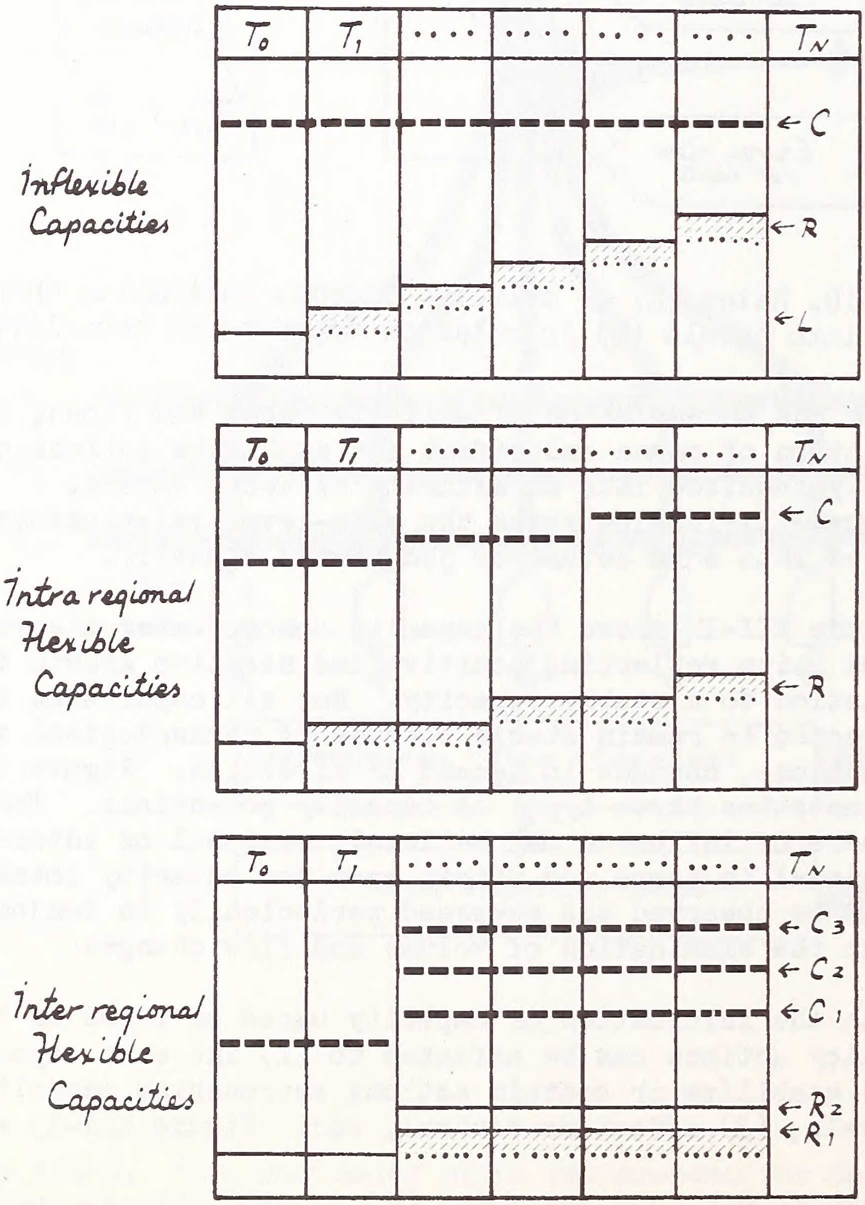


Figure XII-12. Rate-level concepts with static and flexible resource capacities that reflect no change or modifications in standards, technology, or political and social attitudes.

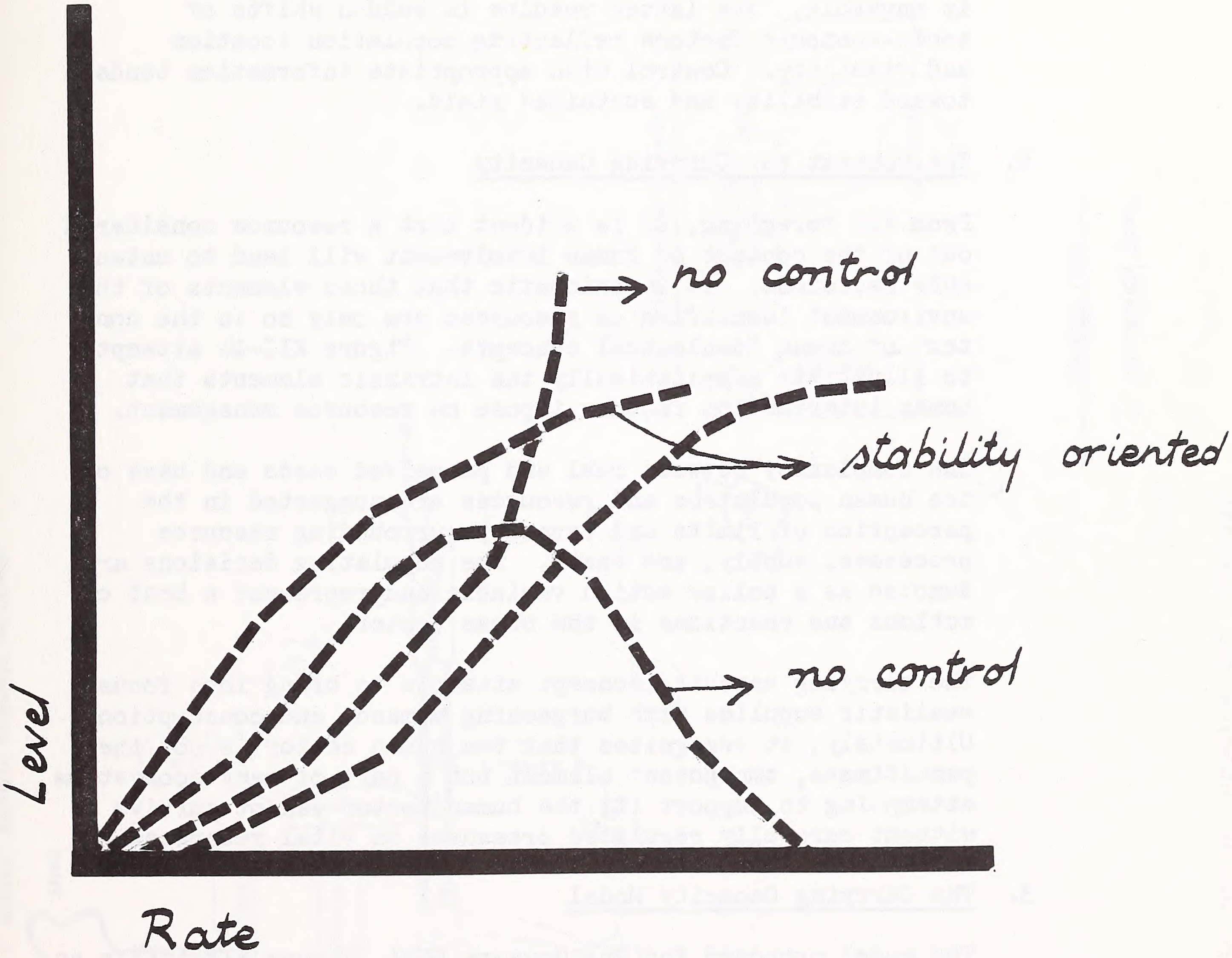


Figure XII-13. A theoretical comparison of controlled resource management versus no control. Resources can be depleted or destroyed; expanded to the displacement of others; or made compatable and stable over the long range.

a few of the potential effects of such regulation. No control may lead to expansion out of balance with resources, exhaust the resource to depletion, or render it unusable. The latter results in sudden shifts of socio-economic factors reflecting population location and viability. Control with appropriate information tends toward stability and sustained yield.

2. The Context for Carrying Capacity

From the foregoing, it is evident that a resource considered out of the context of human involvement will lead to untenable decisions. It is axiomatic that those elements of the environment identified as resources are only so in the context of human ideological concepts. Figure XII-14 attempts to illustrate simplistically the intrinsic elements that human intervention factors impose on resource management.

The complexity between real and perceived needs and uses of the human population and resources are suggested in the perception of limits and capacity surrounding resource processes, supply, and waste. The regulating decisions are denoted as a policy action variable and represent a host of actions and reactions in the human sector.

The carrying capacity concept attempts to bring into focus realistic supplies with burgeoning demands and consumption. Ultimately, it recognizes that the human sector is not the penultimate, omnipotent element but a part of many ecosystems attempting to support it; the human sector cannot survive without carefully regulated pressures on vital resources.

3. The Carrying Capacity Model

The model proposed for The Geysers KGRA, Figure XII-15, is an accounting method for several activities related to geothermal and other resource development. The disclosure mechanism will permit decision-makers to maintain surveillance over a complex of activities and plans which have long-term influences over the form and function of the region and adjacent areas of influence. Capacities or limits, when they are known, can be explicitly identified; appropriate political and technical responses, presumably, can be generated before thresholds are reached.

The use of the model requires: (a) an understanding of the ecosystems involved, i.e., their structure, processes, and interrelationships. Hence, an initial step is a basic resource inventory, embodying information for the region affected, to be developed on intensity scales appropriate

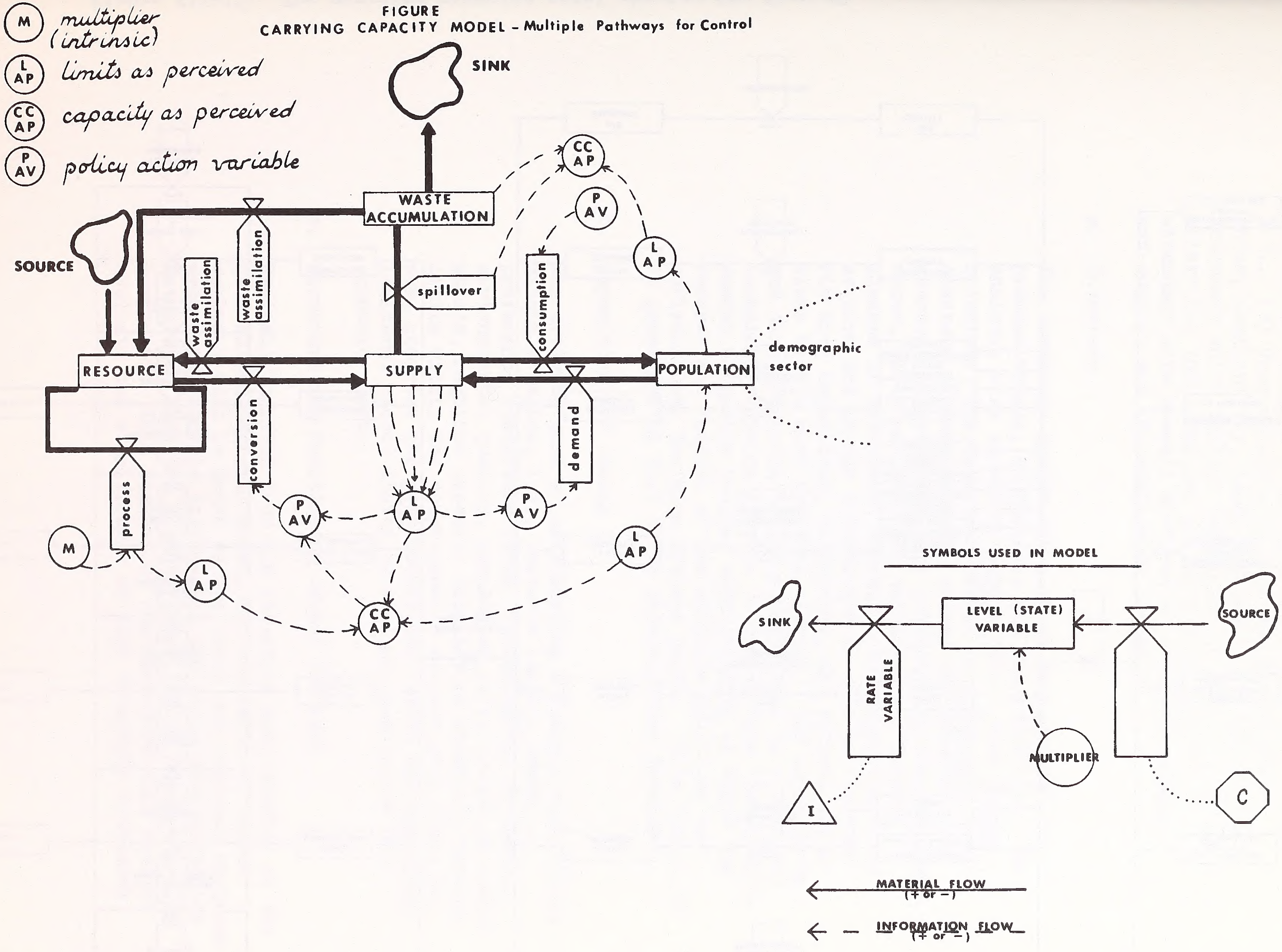


Figure XII-14. The carrying capacity concept showing the intrinsic human impact on resources. Inset: The symbol explanation used in the model and subsequent figures.

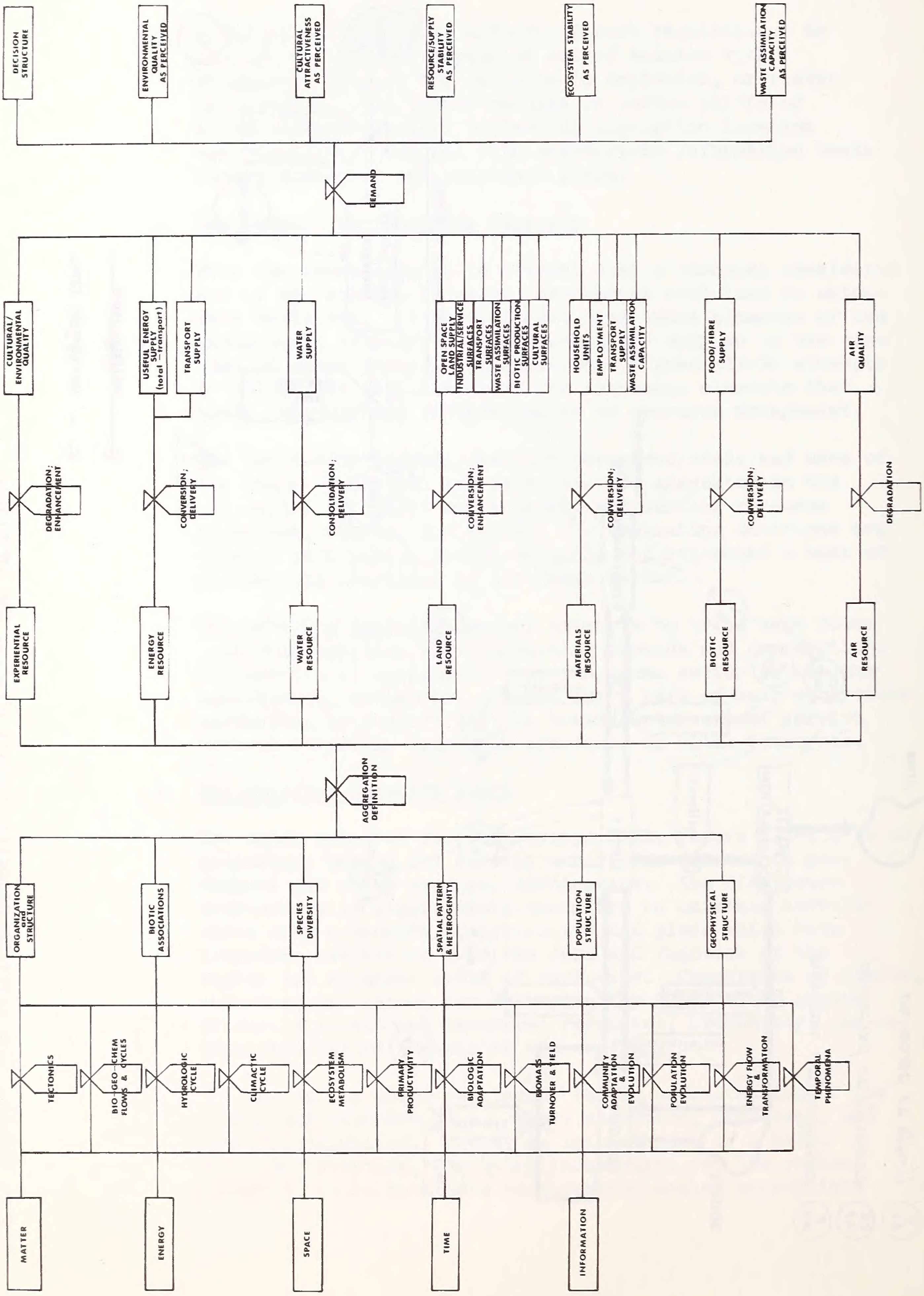


Figure XII-15. The carrying capacity model showing the flow of

for the information's use (cf. Neilson et al., 1974a: 3-7). (b) Resource accounts include the quantity, value, availability, need, and use. (c) Conversion processes which include conversion or economic multipliers and the intricate policy action variables attendant with overall economic or political demand and supply; and (d) evaluation criteria.

a. Inventory

The inventory system needs to be designed for comprehensiveness, simplicity, and accessibility. The analytic bias should be supply rather than demand oriented. The data bias should be resources, i.e., discrete classes of basic energy and material resources, including primary productivity outputs, land, water, waste assimilation capacity, and several classes of investment capital. The objective is to acquire and manage information to seek an improved fit with capacities, tolerances, and optimal conditions within each separate account. The aggregation and disaggregation of informative sets is a critical technical decision process developed from the environmental ecosystem process understanding on which the success and failure of the ultimate political and environmental decision process rests. To be valid, it is prerequisite that it be objective and detailed.

b. Capacities and Limits

The ultimate goal of establishing a dynamic equilibrium within a region, i.e., resource supply, demand,, preference conversion rates, technologies, economies, environmental quality, quality of life, ecosystem homeostasis, requires research identifying stability tending limits within the comprehensive account sets that, in sum, comprise the real (ecosystem based) and perceived (cultural based) limits to regional population and economic growth.

c. Structure and Function of Causal Pathways

Basically derived from the structure and function of the generalized regional model, the portrayal of causal pathways will be keyed to the local and regional decision processes, wherein incremental decisions when summed or integrated comprise a significant though obscure policy component. This element of the procedure will seek to evaluate the significance of such seemingly innocuous, but potentially important decisions that bind resource commitment to irreversible policy, such as the incremental approval of geothermal well sites or public work facilities without a background account system, relating individual decisions to long-range conditions.

d. Institutional Interventions and Societal Goals

This element seeks to identify the policy and decision points within the local, regional, and state intrastructure that, when stimulated, will result in trends toward explicitly identified local and regional goals, including and especially emphasizing the goal of optimum population for maintenance of regional social, economic, and environmental stability with the region's capacities. An example might be the extant policies of federal and state agencies to develop geothermal resources without maintaining environmental impact reporting and enforcement procedures even as inadequate as they are now.

The conceptualization of the integral parts of the Carrying Capacity Model is summarized by cryptic statements in the following list. Expansion of all these also occurs in the discussion of the system found in Appendix V .

SOURCE

1. Universal components
2. Defined as LEVELS
3. Abstract - for conceptualization

ECOSYSTEM PROCESS

1. Universal ecosystem processes
2. Defined as RATES
3. Lie conceptually within ecosystem sector of model
4. Fundamental processes or drivers of the structure and conditions defined as RESOURCES
5. Goals statements possible
6. Flows and properties to be monitored following formulation of goals statements

ECOSYSTEM STRUCTURE

1. Sum of structural components of ecosystems
2. Defined as LEVELS
3. Lie conceptually within ecosystem sector of model
4. Fundamental structure comprising RESOURCES
5. Goals statements possible
6. Properties and changes in value to be defined and monitored following formulation of goals statements

ABSTRACTION

1. Information aggregate formulating definition of RESOURCES
2. Defined conceptually as a RATE (flow)
3. Emergence of human sector from ecosystem sector of model through the abstraction and aggregation of fundamental ecosystem structure and processes
4. Value(s) to the human sector applied
5. Highly variable definition dependent upon physical/biological and cultural/social/physiological requirements and attitudes.

RESOURCE SECTOR ACCOUNTS

1. Bounded sets of value-laden entities principally comprised of subjectively arrayed aggretates of ecosystem structure, function and human process
2. Defined as LEVELS
3. Ecosystem sector and human sector merge
4. Raw material for conversion to SUPPLIES for consumption
5. Value represented symbolically (i.e., money, amenity, property, life support, relative status, etc.)
6. Goals statements possible through recognition of limits
7. Properties and changes in value, through accumulation, depletion or value change to be monitored following formulation of goals statements - explicit portrayal required
8. Capacity statements required

CAUSAL WAVE, FEEDBACK LOOP IDENTIFICATION, MULTIPLIERS

1. Principal intrinsic (non-purposive) systems behavior modifiers
2. Defined as RATE modifiers and causal pathway components
3. Functional components of the ecosystem/human system interface
4. RATES affecting the behavior of the RESOURCE-CONVERSION-SUPPLY sequence to be monitored or estimated

FLOWS

1. Conversion processes - RESOURCE to SUPPLY
2. Defined as RATES
3. Human sector of the model dominates
4. Conversions represent the fundamental human intervention into ecosystem processes and structure
5. Goals statements possible
6. RATES to be monitored and explicitly portrayed

POLICY ACTION VARIABLES, CONVERSION MULTIPLIERS

1. Principal manipulative (purposive) systems behavior modifiers
2. Defined as RATE modifiers and other systems stimulants
3. Principal affectors of FLOWS
4. Principal "window" for systems intervention through alterations in policy, program, design and mitigation

SUPPLY SECTOR ACCOUNTS

1. SUPPLIES are products of RESOURCE conversion which have properties necessary for human consumption
2. Defined as LEVELS
3. Goals statements necessary and based on limitations set by RESOURCES and conversion RATES
4. Capacity statements required in each of the set of disaggregated accounts
5. Properties and changes in value, through accumulation, depletion or value change to be monitored and explicitly portrayed in the context of capacities or limits.
6. Principal factors in the operational Carrying Capacity Model. Long range stability and "fit" are dependent upon the maintenance of RESOURCE and SUPPLY accounts within capacities, limits or tolerances

DEMAND FUNCTION

1. Based on the characteristics of the demographic sector, the demand function is portrayed in the model as the aggregate of demands for SUPPLY, arising variably from each major age class
2. Demand functions and demographic profiles are not disaggregated in the model
3. Defined as a RATE, but not formally developed in the model

EVALUATION CRITERIA

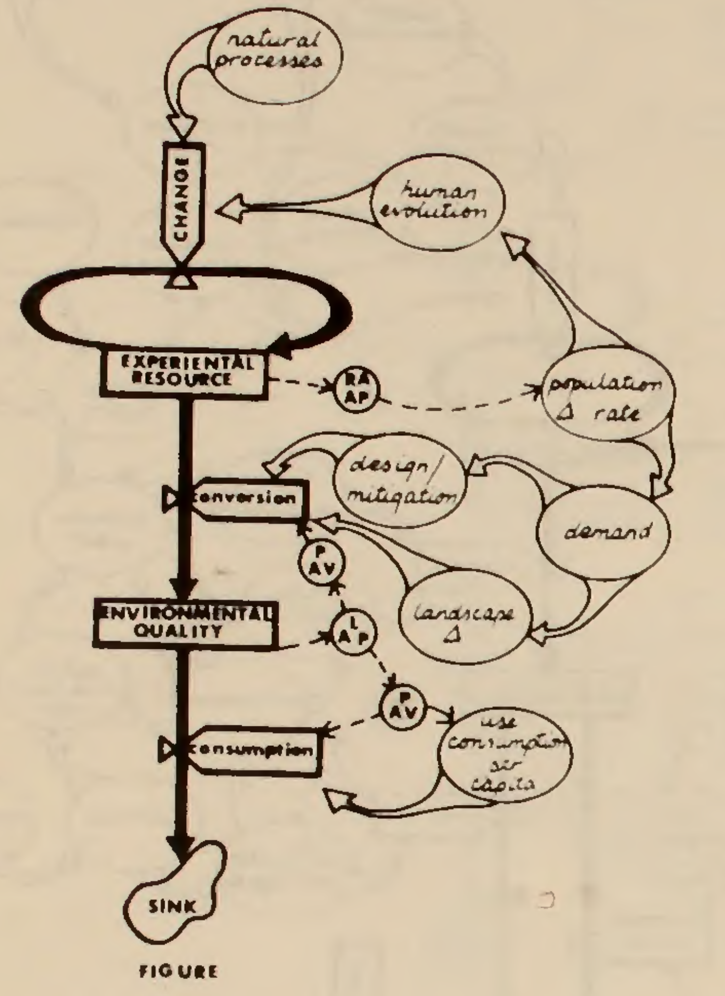
1. Evaluation is not technocratic or judgmental (except in part in the model design), but is based on political (goals seeking) decisions in the context of full disclosure of account balances; absorbtion, accumulation or depletion rates; and capacity statements
2. Regional carrying capacity is determined by RESOURCE and SUPPLY, not Demand enhanced by investment, substitution or technology in an atmosphere of limitless possibility
3. The structure (model) and function (levels, rates, relationships) of the account system and its contents will be systematically portrayed for use in public sector decision-making.

In order to demonstrate the complexity of the interactions a preliminary list of rate equations has been prepared, Table XII-1, as they may apply to The Geysers-Clear Lake KGRA. The interrelationship of the categories between action and reaction is apparent as each resource is identified in the list.

When this list is compared to the tentative list for environmental variables, Table IV-3, necessary to be accounted for in the geothermal development consideration alone, the necessity for a comprehensive information flow base and data retrieval system should be apparent.

The interrelationships between the elements making up and acting upon a given resource are different for each element. Similarly, each perceived limit is different and both reflects and stimulates different policy actions when dealing with each resource. The principal elements of these interactions are illustrated in the following series of diagrams dealing with each resource, Figures XII-16 through XII-22.

When each resource account system is superimposed on the master carrying capacity framework, it will be noted that information flow lines are interconnected between supply sector accounts and evaluation criteria. These interconnections are critical elements indicating potential interrelationships and interdependence. These rather subtle indicators in the system are the principal reason for not summing values within the resources matrix or between resources. It permits instant recognition of critical areas that can readily be translated to capacity levels and therefore indicates potential limiting factors.



SYMBOLS

BAP	*benefit as perceived*
CC	*carrying capacity*
LAP	*limits as perceived*
PAV	*policy action variable*
RA	*rate of assimilation*
RAAP	*rate of assimilation as perceived*

Figure XII-16. The principal factors involved in developing the analysis of the experiencal (aesthetic, etc.) resource component of the model.

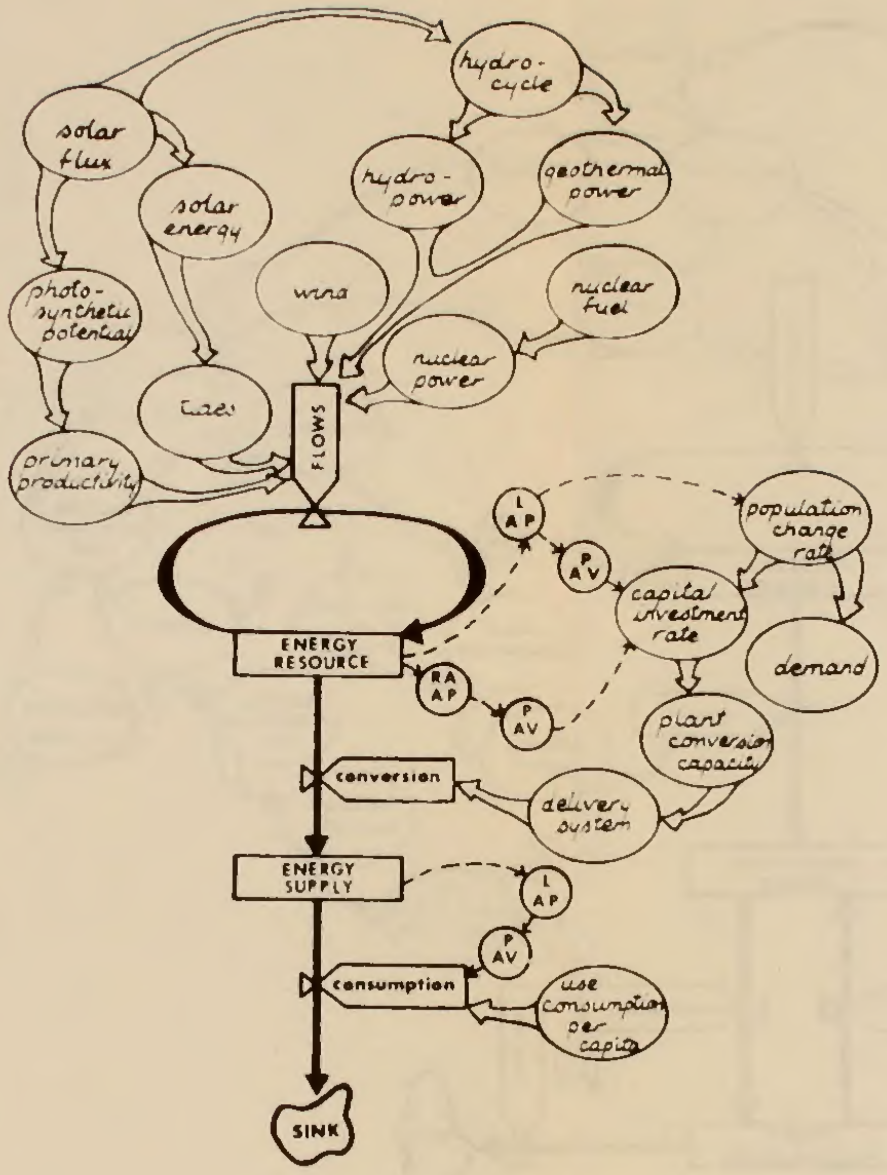


Figure XII-17. The principal factors involved in developing the analysis of the energy resource component of the model.

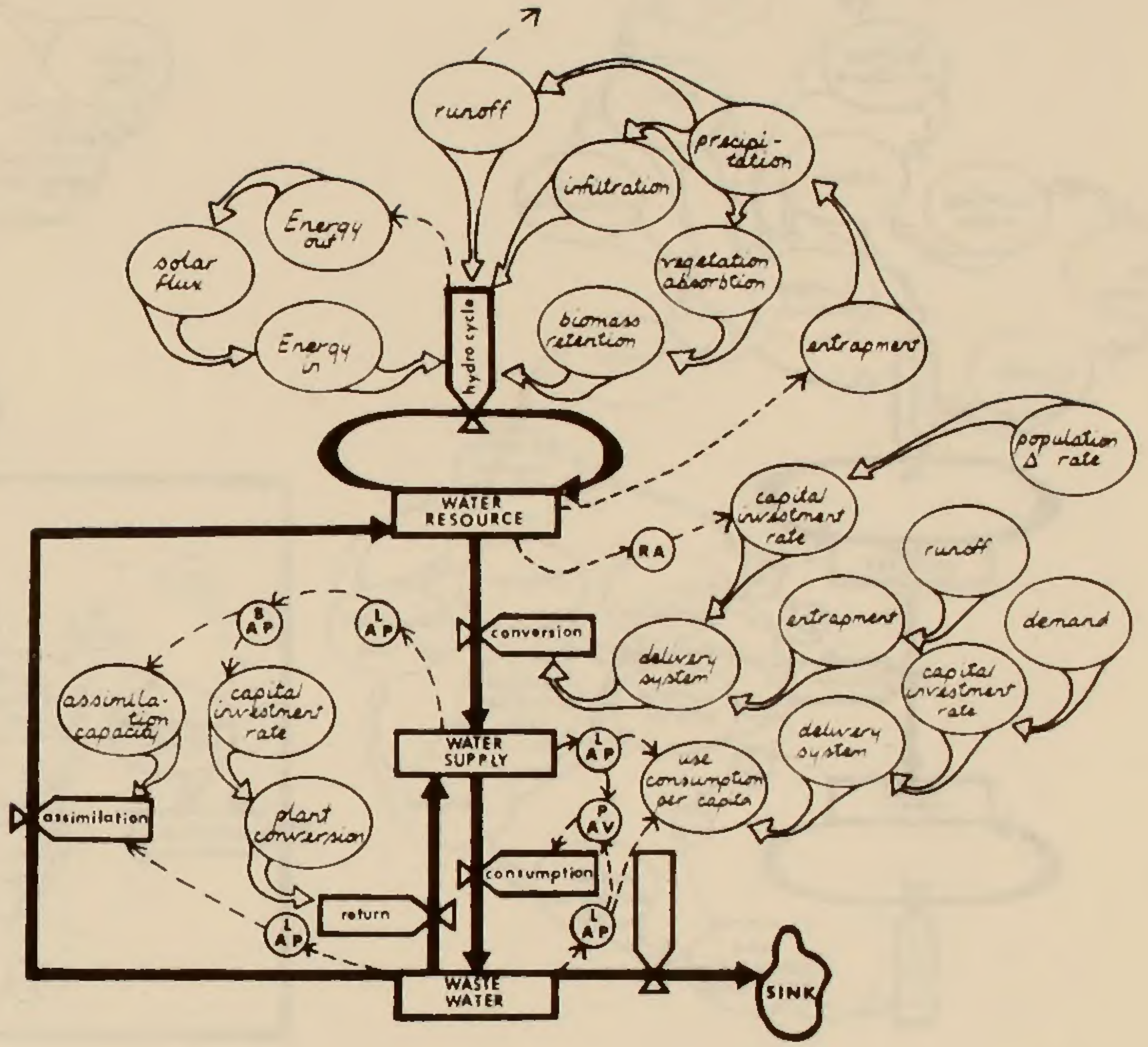
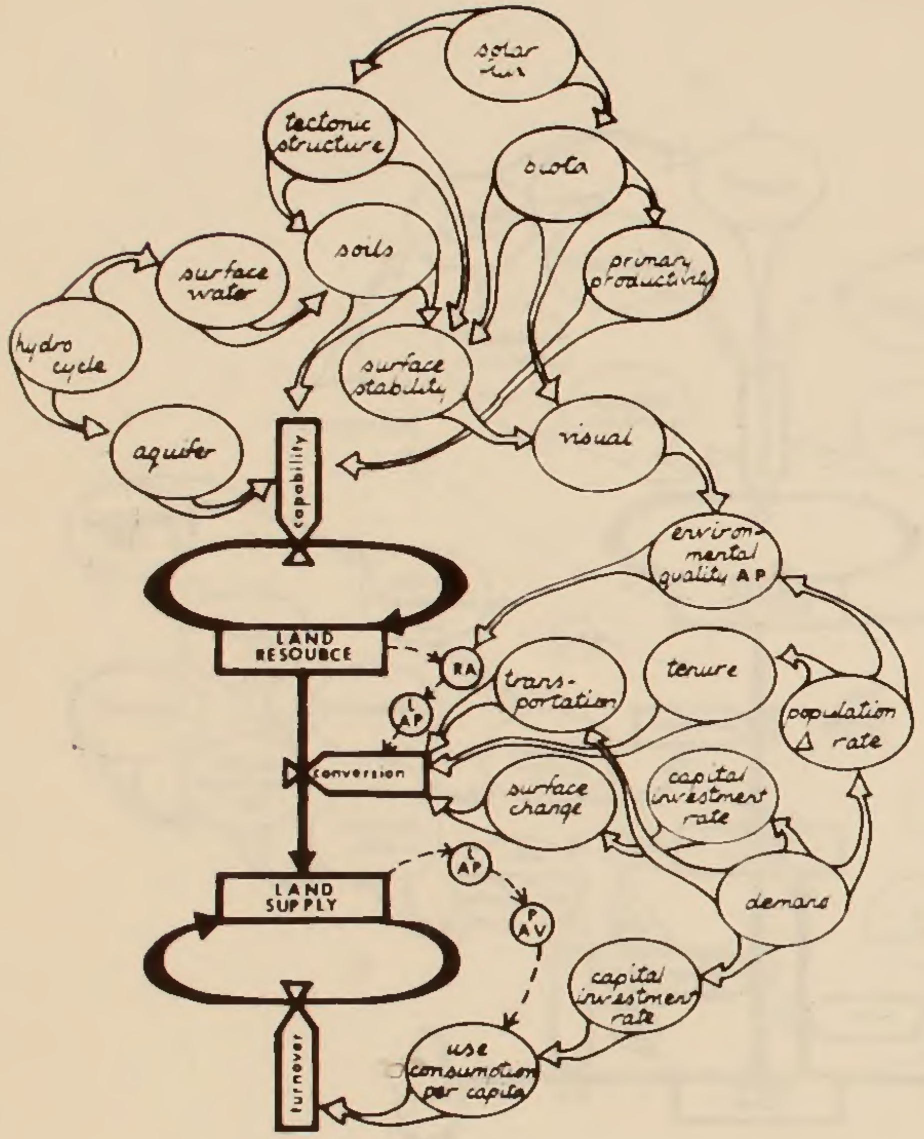
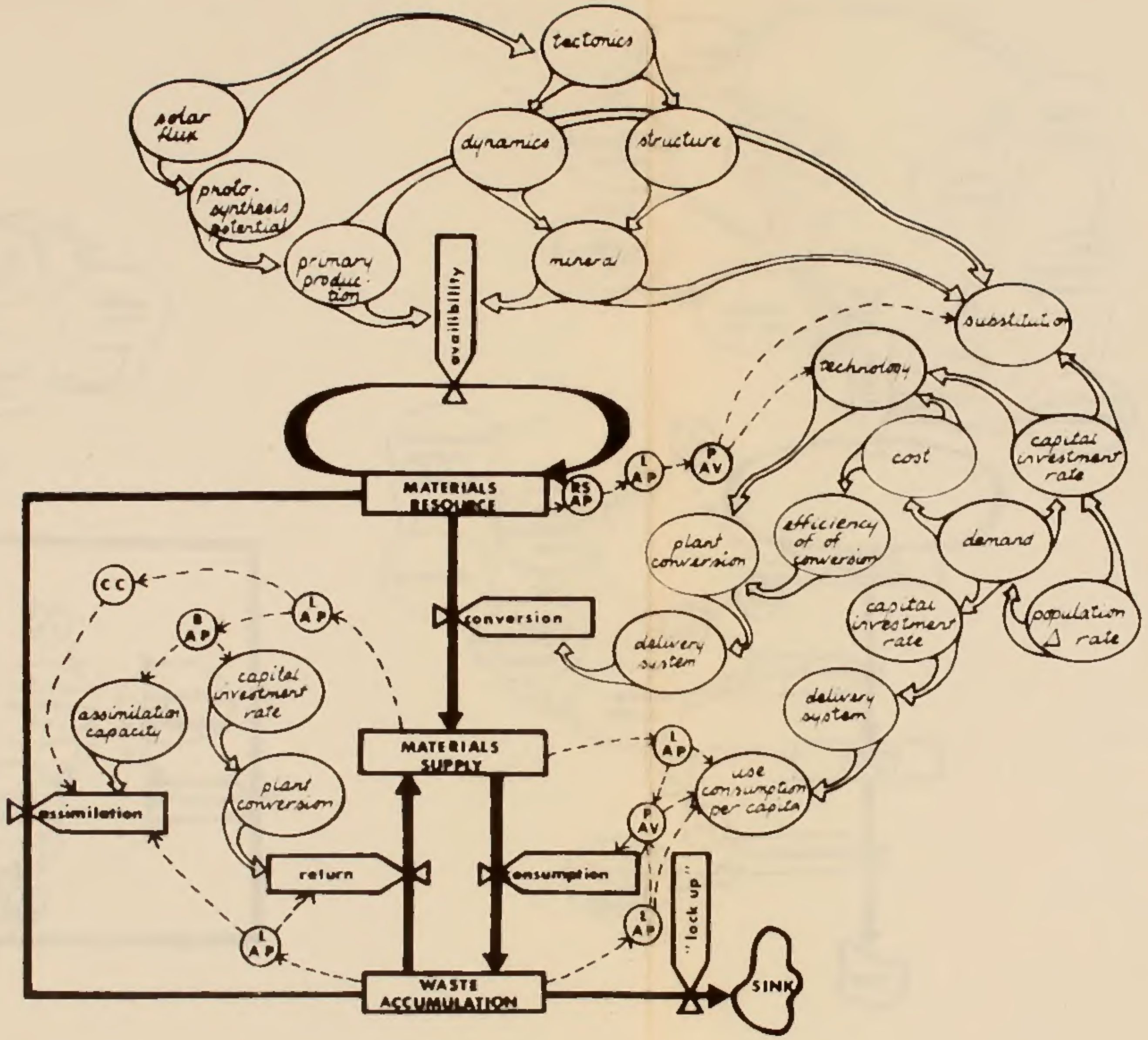


Figure XII-18. Principal factors involved in developing the analysis of the water resource component of the model.



FIGURE

Figure XII-19. Principal factors involved in developing the analysis of the land resource component of the model.



FIGURE

Figure XII-20. The principal factors involved in developing the analysis of the materials resource component of the model.

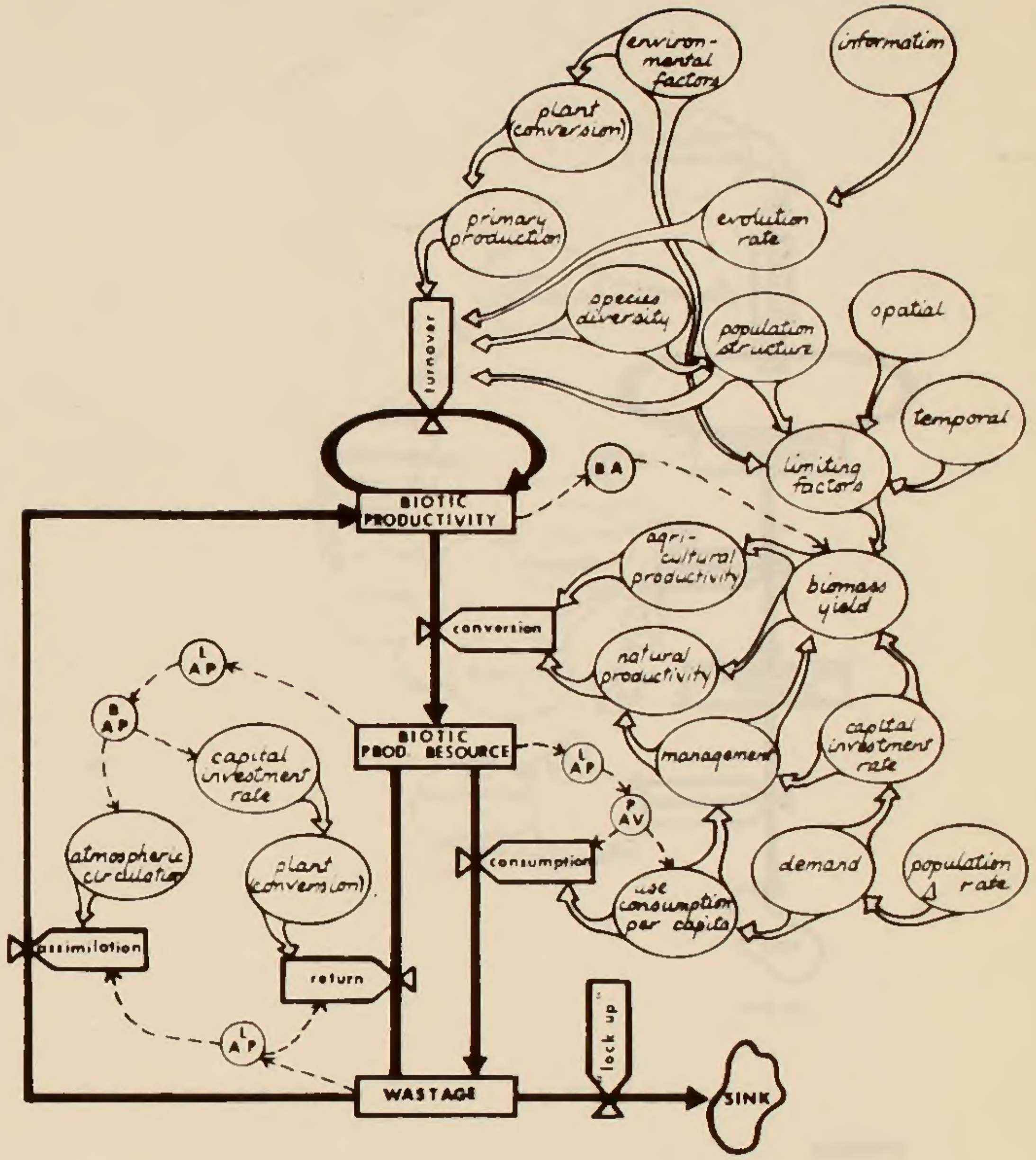
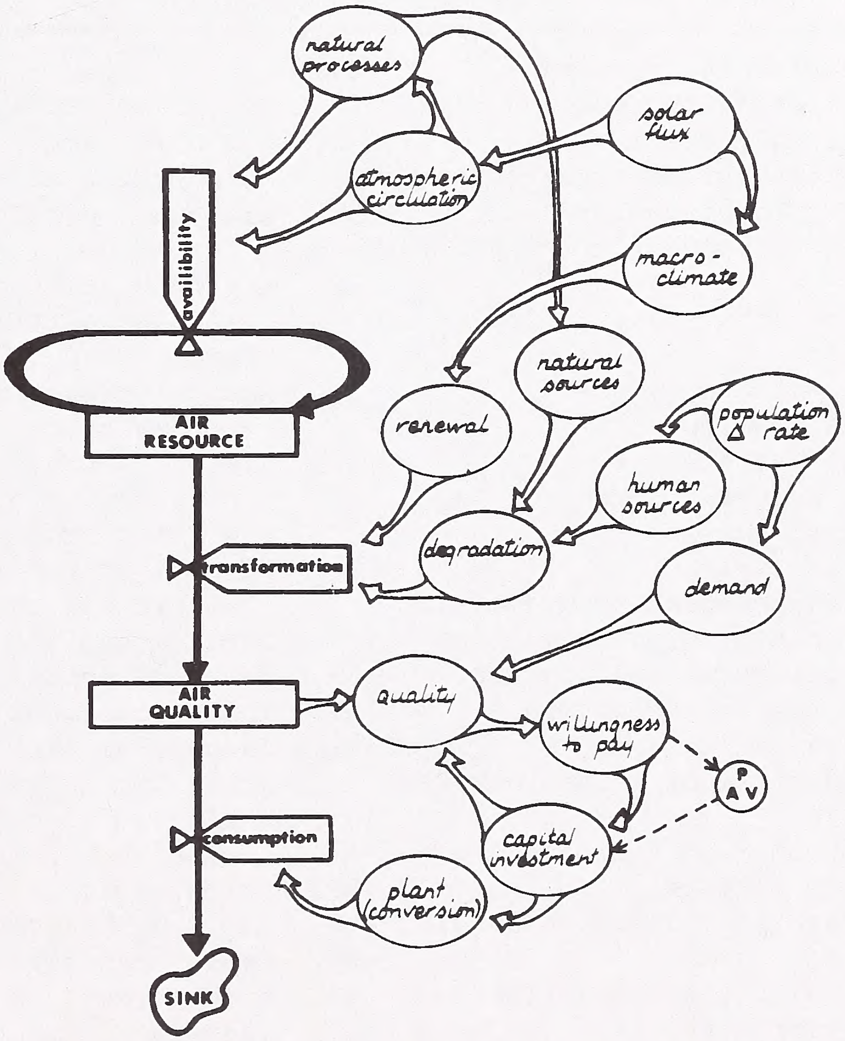


Figure XII-21. The principal factors involved in developing the analysis of the biotic component of the model.



FIGURE

Figure XII-22. Principal factors involved in developing the analysis of the air resource component of the model.

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Table XII-1. Rate equations necessary to evaluate intraresource compatibility and ultimate capacity relationships.

1. Land surface conversion
2. Surface soil displacement
3. Vegetation removal
4. Impervious surface generation
5. Dwelling construction
6. Intra-regional surface water flow
7. Intra-regional aquifer infiltration
8. Intra-regional evapotranspiration
9. Aquifer recharge
10. Inter-regional flows of water (export and import)
11. Water storage
12. Water evaporation from storage and transmission facilities
13. Water delivery to consumers
14. Eutrophication of natural waters
15. Sedimentation of ponded surface waters
16. Toxic/biotic contamination of surface waters
17. Toxic/biotic contamination of aquifer
18. Water pollution absorbtion
19. Primary productivity
20. Aerial gaseous and particulate emission
21. Agricultural land abandonment
22. Agricultural land production startup
23. Timber production for construction within region
24. Timber production for other products
25. Timber production for export
26. Annual grassland (range) production
27. Irrigated pasture production
28. Net livestock production for regional consumption
29.
30. Net livestock export
31. All other agricultural production for regional consumption
32. All other agricultural production for export
33. Agricultural (food) products import
34. Agricultural/timber/livestock waste production
35. Agricultural/timber/livestock waste accumulation
36. Fisheries production for regional consumption
37. Fisheries production for export
38. Mineral extraction for construction within region
39. Service capital investment rate
40. Service capital depreciation rate
41. Industrial capital investment rate
42. Industrial capital depreciation rate
43. Agricultural capital investment rate
44. Agricultural capital depreciation rate
45. Colonization
46. Employment generation
47. Employment termination (net)
48. Unemployment rate
49. Industrial production (net/gross regional product)
50. Industrial export
51. Industrial import
52. Deaths/year/age class
53. Births/year/age class
54. Immigration/year/age class
55. Emigration/year/age class